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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF CHEMISTRY—BULLETIN NO. 110.

H. W. WILEY, Chief of Bureau.

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CHEMICAL ANALYSIS AND COMPOSITION OF AMERICAN HONEYS,

BY

C. A. BROWNE,
Chief of Sugar Laboratory,

INCLUDING

A MICROSCOPICAL STUDY OF HONEY POLLEN,

BY

W. J. YOUNG,
Assistant, Microchemical Laboratory.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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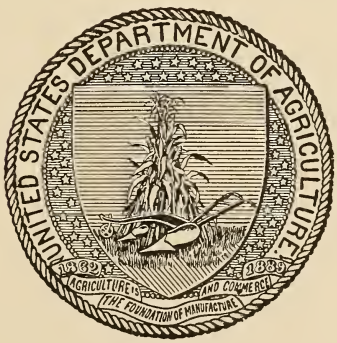

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Chemistry,
Washington, D. C., October 31, 1907.

Sir: I have the honor to submit for your inspection and approval a manuscript containing the results of investigations made in the sugar and microchemical laboratories of this Bureau upon the analysis and composition of American honeys and the microscopic examination of the same. Dr. E. F. Phillips, in charge of apiculture in the Bureau of Entomology, rendered most valuable assistance in procuring samples of pure honey for investigation and offered many practical sugestions from the bee keeper's point of view. The samples of Hawaiian honeys examined were furnished by Mr. D. L. Van Dine, entomologist of the Hawaiian Agricultural Experiment Station, who also supplied information upon the complex conditions which affect the composition of Hawaiian honeys.

I recommend that this report be published as Bulletin No. 110 of the Bureau of Chemistry.

Respectfully,

H. W. Wiley,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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CHEMICAL ANALYSIS AND COMPOSITION OF AMERICAN HONEYS.

INTRODUCTION.

Miscellaneous analyses of American honeys have been published during past years in bulletins of a number of the State agricultural experiment stations, in various chemical journals, and in the several periodicals devoted to bee keeping, but up to the present time no attempts have been made toward making a systematic study of the honeys produced in the United States. Our knowledge of the general and local conditions which affect the composition of honey is exceedingly limited, and the present bulletin was begun with the hope of making a partial contribution to the information upon this subject. As the work progressed, however, it soon became evident that many more than the one hundred analyses made would be required before any conclusions, except those of a very general character, could be drawn.

The main purpose with which the work was undertaken was threefold: First, to determine the general composition of our native honeys, with particular reference to the effects of different floral nectars and of local conditions of environment. Second, to establish a general range for the variation in the composition of American honeys which would be of assistance to the food chemist in the examination of commercial samples. The recent passage of the food and drugs act and the unfortunate extent to which the adulteration of extracted honey and honey preparations has been practiced in this and foreign countries have rendered the establishment of a uniform basis of comparison exceedingly necessary. The third object was to investigate and improve, if possible, the official methods of honey analysis. In many respects, especially in deciding between abnormal and adulterated honeys, the methods of analysis usually followed are very defective, and a detailed study of the methods used in this and other countries was undertaken with the hope of improving them.

In addition to the three main lines of investigation, a number of other questions which have a bearing upon the chemistry of honey were touched upon, such as the relationship of honeydew, gums, and other plant exudations to honey and the effects of artificial feeding of bees upon the composition of the resulting product.

DEFINITION OF THE TERM "HONEY."

The treatment of the subject of honey chemistry will depend, necessarily, upon a proper understanding of the term "honey." According to the committee on food standards of the Association of Official Agricultural Chemists,[a] honey is the nectar and saccharine exudations of plants gathered, modified, and stored in the comb by honeybees (*Apis mellifica* and *Apis dorsata*). According to Blythe[b] "honey is the saccharine matter collected and stored by one particular species of bee (*Apis mellifica*)." According to the Vereinbarungen Nahrungs- und Genussmittel[c] honey is the nectar obtained from flowers by worker bees, which, after modification in the honey stomach of the latter, is stored in the cells of the comb for the nourishment of the young brood. Still more precise is the definition given in the Century dictionary: "Honey is a sweet viscid fluid collected from the nectaries of flowers and elaborated for food by several kinds of insects, especially by the honeybee (*Apis mellifica*). Bees often fill their cells with other substances than the nectar of flowers, as molasses, honeydew, or the juices of fruits, but the product is not true honey." For practical purposes the latter definition is too narrow, for bees almost always gather variable amounts of plant exudations other than nectar.

The great difference of opinion regarding the term "honey" is brought out in the discussion by the committee for the revision of the section upon honey in the "Vereinbarungen"[d] where it is variously defined as the product "derived by bees from plant substances" in general, "from natural plant juices" only, from "the unchanged natural juices," from the "nectar or juices of living plants," etc.

SOURCES OF HONEY.

COMPOSITION OF FLORAL NECTAR, ETC.

Chemically considered, the ideal honey is a concentrated solution of invert sugar (i. e., of the sugars dextrose and levulose in equal proportions), with traces of ash, formic acid, nitrogenous bodies, dextrin, and other organic substances not sugar. This ideal type of honey, unfortunately, is the exception, since the impurities so generally introduced by bees from plant juices, honeydew, and other sources affect the composition of honey to a very marked degree. A limit, even if it be an arbitrary one, must therefore be set for the percentage of such impurities, in order that a suitable standard may be maintained for the composition of honeys sold upon the market.

---

[a] U. S. Dept. Agr., Office of the Secretary, Cir. 19, p. 11.

[b] Foods, 5th ed., 123.

[c] 1899, p. 116.

[d] Zts. Nahr. Genussm., 1907, *14*: 24.

Before taking up the composition of honey itself it will be well to consider briefly the composition of floral nectar and other plant exudations and the manner in which these are modified by the bees.

A. S. Wilson [a] has determined the amount of reducing sugar and cane sugar in various flowers with the following results:

Determination of reducing sugar and cane sugar in various flowers (Wilson).

Variety of flower.	Reducing sugar.	Cane sugar.
	Milligrams.	*Milligrams.*
Fuchsia, per flower	1.69	5.9
Claytonia alsinoides, per flower	.175	.238
Everlasting pea, per flower	8.33	1.60
Vetch (*Vicia cracca*), per raceme	3.15	.01
Vetch, per single flower	.158	
Red clover, per head	5.95	1.98
Red clover, per floret	.099	.033
Monkshead, per flower	4.63	1.78

From these results Wilson has estimated that in the case of the clover, bees would have to make 2,500,000 visits to secure 1 pound of honey. Estimates by König [b] for various flowers show that bees would have to visit from 100,000 to 2,000,000 flowers to obtain 1 kilogram (about 2 pounds) of honey.

A. von Planta [c] has given the following analyses of nectars from several varieties of flowers:

Analyses of nectars from various flowers (von Planta).

Nectar.	Water.	Reducing sugar.	Cane sugar.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Protea mellifera	82.34	17.06		
Bignonia radicans	84.70	14.84	0.44	0.45
Hoya carnosa	59.23	4.99	35.65	.11

An analysis of the nectar of the honeysuckle quoted by Bonnier [d] gives water, 76 per cent; reducing sugar, 9 per cent; sucrose, 12 per cent; dextrin, ash, etc., 3 per cent.

EVAPORATION OF NECTAR.

In the modification of the nectar by the bees several changes in composition are produced. Among the most important of these is the evaporation of the nectar to a water content of about 20 per cent. This is effected in the hive by the bees exposing the nectar in thin layers to the action of a current of air produced by the fanning of their wings. This evaporation is further hastened, according to some,

[a] Chem. News, 1878, *38*: 93.

[b] Chem. Nahr. Genussm., *2*: 995.

[c] Zts. physiol. Chem., 1886, *10*: 227.

[d] Sources of Honey, Sci. Amer. Suppl., August 10, 1907, p. 92.

by a process of regurgitation, the nectar being continually thrown out from the honey sac on the partly doubled tongue and then drawn in again until, by the movement of the air and the heat of the hive, the nectar is sufficiently reduced to be deposited in the cells of the comb.

Another change of considerable importance which takes place while the nectar is in the honey sac of the bee, and also probably during evaporation and storage in the comb, is the inversion of a considerable part of the sucrose in the nectar through the action of an inverting enzym secreted by the bee. Bonnier[a] gives the following percentages of sugars of sainfoin nectar and sainfoin honey:

Percentage of total sugar in sainfoin nectar and sainfoin honey (Bonnier).

Kind of sugar.	Sainfoin nectar.	Sainfoin honey.
	Per cent.	*Per cent.*
Cane sugar (sucrose)	57.2	8.2
Dextrose and levulose	42.8	91.8

These figures show that over 85 per cent of the sucrose in the original nectar had been inverted.

Another modification produced in the nectar by the bees is the introduction of a minute quantity of formic acid. This acid is wanting in the pollen and nectar of flowers and is supposed to be introduced into the honey by the bee just previous to capping the cell. The formic acid thus introduced by the bee is supposed to act as a preservative and prevent the honey from fermenting.[b]

HONEYDEW.

While nectar is the principal and purest source of food for bees, there are other exudations from which they may gather honey and which must always be taken into account by the chemist in honey analysis. The most important and common of such exudations is what is known as honeydew. Bonnier, writing on sources of honey, says:

> Honeydew exudes not from special nectaries, but from the general surface of young and even full-grown leaves. Honeydew may be produced annually on very hot days, and it is exceedingly abundant in very dry seasons, when it forms a valuable supply for the bees, although it yields an inferior honey owing to the presence of gum and dextrin. The trees and shrubs which most frequently produce honeydew in France are the oak, ash, linden, maple, poplar, birch, hazel, mountain ash, blackberry, and barberry. It is occasionally found also on certain herbaceous plants, including salsify, scorzonera, and some cruciferæ. Usually the honeydew is excreted or rejected by plant lice (aphides), which extract the sweet sap of leaves, but digest only a small portion of it.

[a] Loc. cit.

[b] König, Chem. Nahr. Genussm., 2: 995.

This variety is known in France as *miellat*. But honeydew is sometimes exuded directly from the stomata of leaves in the absence of plant lice. This variety is true honeydew, or *miellée*.

Honeydew differs from floral nectar in composition in several important particulars. E. v. Raumer [a] gives the following composition of honeydew obtained from maple leaves:

	Per cent of dry substance.
Sugar before inversion	16.70
Sugar after inversion	28.50
Dextrins after fermentation with yeast	39.40
Ash	3.02
Nitrogenous matter as albumin	3.17

Unger [b] gives the following percentage for the dry matter of two honeydews:

Analyses of honeydews (Unger).

Honeydews.	Reducing sugar.	Gums.	Insoluble	Mannite, ash, etc.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Carpinus betulus	25.31	8.59	.....	.....
Juglans regia	25.52	19.85	0.75	53.88

Analyses by Boussingault [c] give the following data for the dry substance of two honeydews:

Analyses of two honeydews by Boussingault.

Determinations.	Collected July 22.	Collected August 1.
	Per cent.	*Per cent.*
Cane sugar	48.86	55.44
Reducing sugar	28.59	24.75
Dextrin, etc	22.55	19.81

Analyses by Wiley [d] of honeydew from the pine tree gave the following results:

	Per cent.
Water	54.41
Sucrose	8.16
Invert sugar	17.44
Dextrin, etc. [$(\alpha)_D = +105$]	19.99

The honeydew itself was dextrorotatory, but the resulting honey levorotatory, from which it was inferred that the bees had brought about an inversion.

The various analyses of honeydew quoted all show a high preponderance of ash and of gum or dextrin as compared with floral nectar. These dextrins may be derived in part from the juice of

[a] Zts. anal. Chem., 1894, *33*: 397.

[b] Ber. Kais. Acad. Wissensch. Wien, Mathematisch-Naturwissenschaftliche Classe, 1857, *25*: 449.

[c] Compt. rend., 1872, *74*: 87.

[d] Amer. Chem. J., *13*: 24.

the leaf; it is more probable, however, that they are produced after exudation by fermentation through the agency of gum or dextran-producing bacteria.

Among other constituents occurring in honeydew and not in floral nectar should be mentioned dulcite, found by Maquenne[a] in honeydew from *Euonymus japonica*, and melezitose, found by the same authority[b] to the extent of 40 per cent in honeydew from the linden. The question of honeydew and its bearing upon the composition of honey will be discussed more fully under the subject of abnormal honey.

DESCRIPTION OF SAMPLES ANALYZED.

Over one hundred samples of pure honey were analyzed in this investigation. The honeys represent the product from about fifty different varieties of flowers and were widely distributed, having been gathered from thirty-two States and Territories. Of the samples analyzed several were excluded from the table either on account of doubt as to origin or because the samples had changed in composition through long standing. Eighty-five of the samples were part of a honey exhibit made at the St. Louis Exposition in 1903 by the National Bee Keepers' Association, this exhibit being afterwards donated to the Bureau of Entomology. The following account of this honey display is furnished by Mr. France,[c] of Platteville, Wis., general manager of the association:

> To make a display of honey both attractive and educational, I asked the National Bee Keepers' Association members in every State to save carefully and separately the various kinds of honey produced in their locality. Many bee keepers expressed their willingness to help me, but said it was a poor season with them, and there were but few kinds of honey they could secure. A large United States map was fastened to the north wall of the Convention Hall, then bracket shelves were placed across each State, Canada, and Cuba, and on them I put most of the honey, in 157 1-pound clear glass jars with aluminum screw top.

The samples from Mr. France were received in the exposition jars, with their original labels. The Canadian and Cuban samples were not included in the number analyzed. Of the remaining fifteen samples eleven were Hawaiian honeys furnished by Mr. D. L. Van Dine, entomologist of the Hawaii Agricultural Experiment Station in Honolulu, and four were New England honeys supplied by the Bureau of Entomology.

All of the samples had been previously extracted or strained. In several cases where this had been imperfectly performed, the finely divided fragments of comb were removed by filtering the liquefied honey through cloth.

---

[a] Bul. soc. chim. Par., (3) *21*: 1082.

[b] Compt. rend., *117*: 127.

[c] Amer. Bee J., Jan. 5, 1905, p. 5.

The detailed description of the samples is given in the table beginning on page 22.

PREPARATION OF SAMPLES FOR ANALYSIS.

When the honeys were free from granulation and in a perfectly liquid condition, no preparation was necessary. Samples of honeys

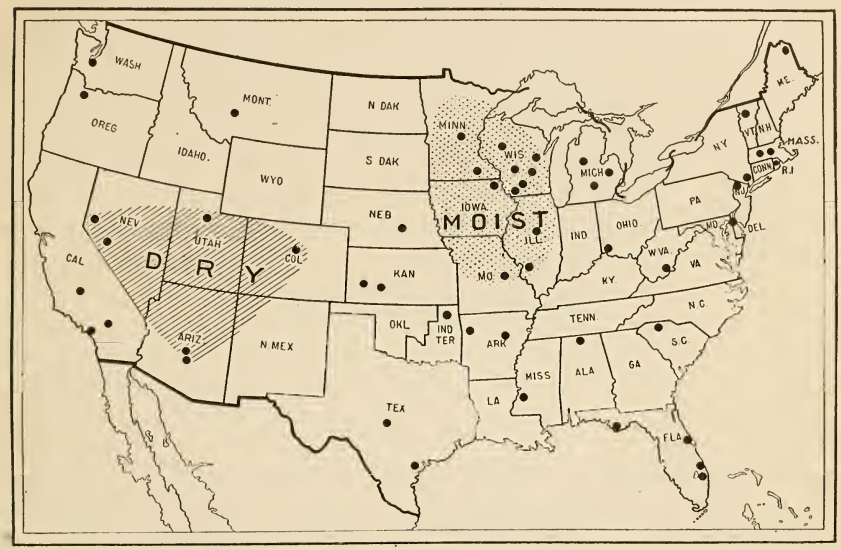

FIG. 1.—Distribution of honeys analyzed, showing areas of low and high average humidity.
In the dry area: Average annual humidity, 51 per cent; average annual rainfall, 10.6 inches; average moisture content of honeys, 15.09 per cent.
In the moist area: Average annual humidity, 76 per cent; average annual rainfall, 30.9 inches; average water in honeys, 18.88 per cent.

which had granulated (as was generally the case) were carefully warmed by placing the loosely stoppered bottles in a bath of water warmed to 45° to 50° C. until complete solution of the crystallized dextrose was effected. The samples, after thorough mixing, were cooled, when they were ready for analysis.

Error due to imperfect samples of honey.—A very serious error may be introduced into the analysis of honey by imperfect sampling. This applies not only to the sampling of bottled honeys in the laboratory, but also to the sampling of honeys in bulk by inspectors. Nearly all honeys granulate more or less readily, and the result is that a compact crystalline deposit of dextrose settles at the bottom of the container, leaving in solution a greater preponderance of the less readily crystallizable sugar levulose. Leaky containers for the same reason may cause a serious error in the determination of the analytical constants of a honey. Samples taken from the liquid surface and from the crystalline bottom layer of such honeys will show the greatest difference in composition; hence the necessity of thoroughly mixing the contents of a container before sampling. In

the laboratory this should be done by melting. If honeys are sampled in bulk from casks or barrels melting is impracticable, and the most that the inspector can do is to mix the contents as well as possible by shaking and stirring before taking the sample for analysis.

Errors due to changes in composition during storage.—It is exceedingly important in making analyses of honey that the work be begun immediately upon the receipt of the samples. Changes in composition may take place through fermentation by yeasts and bacteria, or even through the agency of inverting enzyms left in the honey by the bees (page 12). It has happened in the experience of the Bureau of Chemistry that samples of honey taken by inspectors from casks and bottled and sealed have decreased considerably in sucrose content within four months. Inspection samples of raw honeys from casks should be sterilized to destroy micro-organisms and enzyms before bottling and sealing.

METHODS OF ANALYSIS.

Unfortunately the quantity of sample available for analysis was so small in nearly every case that a detailed study of the less commonly determined components of honey, such as make up the organic solids, not sugars, could not be undertaken. Only the more usual physical and chemical constants were determined, these including the direct and invert polarizations at both 20° and 87° C., and the percentages of water, invert sugar, sucrose, ash, dextrin, and acidity. In a few cases in which the quantity of the samples was sufficient, determinations of nitrogen and pentosans also were made.

The methods of analysis employed were in general those of the Association of Official Agricultural Chemists, as given in Bulletin 107 of the Bureau of Chemistry.

OPTICAL METHODS.

DIRECT POLARIZATION.

For the direct polarization of the honeys the normal weight (26 grams) of the liquefied sample was dissolved to 100 metric cubic centimeters at 20° C. after the addition of 5 cubic centimeters of alumina cream. The solution was filtered and immediately polarized in a 200-millimeter tube in a Schmidt and Haensch triple sha saccharimeter at 20° C. The same solution was again polar after eighteen to twenty hours standing, the second reading being taken as the constant polarization of the honey. The difference between the immediate and constant polarization was taken as the birotation.

After taking the constant reading at 20° C. the solution was brought to a temperature of 87° and again polarized. The temperature was maintained at 87° by means of a current of hot water, and consta readings could usually be secured within five minutes. The fie

was never so clearly marked at 87° as at 20° on account of slight striations produced in the heated liquid, hence readings could not be made with the same degree of accuracy as at the lower temperature. Nevertheless, consecutive readings could usually be obtained agreeing within one or two-tenths of a degree.

INVERT POLARIZATION.

Fifty cubic centimeters of the solution for the direct polarization were made up to 55 cc in a small sugar flask with concentrated hydrochloric acid at 20° C. and allowed to remain at the laboratory temperature over night (18 to 20 hours). The solution was then polarized in a 200 mm silver-lined jacketed polarization tube, first at 20° and then at 87°, as in the case of direct polarization. The hydrochloric acid of the inverted solution had no perceptible action upon the silver lining of the tubes. In case silver-lined tubes are not available, the acid of the inverted solution should be neutralized[a] to avoid its attacking the metal walls. The invert saccharimeter readings at 20° and 87° were increased by one-tenth to correct for dilution, and the values thus obtained were recorded.

CALCULATION OF LEVULOSE.

Inasmuch as the variations in polarization at different temperatures are due almost entirely to the change in specific rotation of levulose, it is possible to calculate with a fair degree of approximation the levulose content of any saccharine solution. Wiley's[b] optical method for estimating levulose is based upon this principle. In the method as described by Wiley it is shown that 1 gram of levulose in 100 cc shows a variation of 0.0357° V. for each degree centigrade; the variation for 67° would, therefore, be 2.3919. The difference in the direct polarization of a honey at 20° and 87° C. divided by 2.3919 will give, therefore, the grams of levulose in a normal weight of honey; from this the percentage of levulose may be obtained easily. The above method of calculation, however, only holds for solutions which have been made up at 20° and 87°. The polarizations at 87° in the table (page 23) were all made upon solutions prepared at 20°, so that a correction must be introduced for the dilution due to the expansion of the liquid. One hundred cubic centimeters of water at 20° will expand to 103.15 cc at 87°; the polarization at 87° must, therefore, be multiplied by 1.0315 to obtain the reading corrected for this expansion. The uncorrected readings at 87° are

[a] It is always much the better plan to neutralize before polarizing the inverted solution at 87° C., on account of the danger of destroying part of the levulose. (See p. 44.)

[b] Principles and Practice of Agricultural Analysis, 1897, 3: 267.

given in the table and these are sufficient for purposes of comparison; if it is desired to calculate the percentage of levulose, however, it is important that this correction be made.

CHEMICAL METHODS.

MOISTURE.

For the determination of moisture in honeys 2 grams of the sample were weighed out in a flat-bottom aluminum dish (2½ inches in diameter) containing from 10 to 15 grams of fine quartz sand which had been thoroughly washed and ignited. A small glass stirring rod was weighed out with the dish and sand, and after the addition of the honey the latter was dissolved in 5 to 10 cc of distilled water and thoroughly incorporated with the sand by stirring with the rod. The dishes were then placed in a vacuum oven and dried at 65° to 70° C., under 20 to 24 inches vacuum, to constancy in weight. The average length of time required for drying the samples was about eighteen hours; with honeys of high purity, such as those of the alfalfa and clover type, twelve hours' drying or even less was sufficient, while with low-grade honeys of the honeydew class, which were high in dextrins and gums, thirty-six hours or longer were required to secure constancy in weight.

REDUCING SUGARS.

As dextrose.—Ten cubic centimeters of the solution used for the direct polarization (26 grams to 100 cc) were made up to 250 cc and the reducing sugars as dextrose in 25 cc of this solution determined by Allihn's method.

As invert sugar.—The dextrose by Allihn's table was converted into invert sugar by multiplying by the factor 1.044.[a]

CALCULATION OF DEXTROSE.

The method of calculating the levulose content of honeys from the difference in polarization between 20° and 87° has already been given. The percentage of levulose subtracted from the total reducing sugar as invert will give very closely the percentage of dextrose if these two sugars are present in nearly equal amounts. If the two sugars differ widely in the percentages, an error[b] is introduced into the calculation of invert sugar and hence into the percentage of dextrose. It is therefore more accurate to reduce the levulose to its

[a] Browne, Analysis of Sugar Mixtures, J. Amer. Chem. Soc., 1906, *28*: 446. For the same weight of reduced copper the ratio $\frac{\text{Dextrose}}{\text{Invert Sugar}} = 0.958$ and $\frac{\text{Invert Sugar}}{\text{Dextrose}} = 1.044$.

[b] Lippmann, Chemie der Zuckerarten, *1*: 898.

dextrose equivalent in copper-reducing power by multiplying by the factor 0.915.[a] This subtracted from the total reducing sugars as dextrose will give the true percentage of dextrose.

SUCROSE.

On account of the various errors involved in the estimation of sucrose in honeys by the Clerget method of double polarization (such as the difference in specific rotation of levulose in neutral and acid solution), the sucrose was determined in the honeys by the gravimetric method. Ten cubic centimeters of the solution used for invert polarization were made up to 250 cc after neutralizing the free acid with sodium carbonate, and the invert sugar determined as before. The difference between the percentage of invert sugar as found before and after inversion multiplied by 0.95 gives the percentage of sucrose.

ASH.

Five grams of honey were carefully heated in a platinum dish until intumescence ceased and then ignited at low redness until a white ash was obtained.

With impure honeys of the honeydew class, which are usually high in ash content, it is sometimes necessary first to carbonize the honey and wash out the soluble salts with hot distilled water; this solution is then added to the ash from the leached char, and the whole evaporated and ignited at low redness as before.

DEXTRIN.

The determination of the dextrin bodies in honey was attempted by a number of different methods, but none of these was found to be reliable or altogether accurate. The methods based upon the removal of the sugars by fermentation and determination of the residual dextrins were found to be inaccurate on account of a partial fermentation of the honey dextrins. Methods based upon the increase in copper-reducing power after heating with hydrochloric acid gave too low results on account of a partial destruction of levulose. Methods based upon a precipitation of the dextrins by means of absolute alcohol and weighing of the same after drying were also found inaccurate on account of the occlusion of sugars in the dextrin precipitate. The method finally adopted in the present work was a modification of the alcohol precipitation method and was carried out as follows:

Eight grams of honey were transferred to a 100 cc flask with 4 cc of water and sufficient absolute alcohol to complete to the mark. A little care is required to effect the complete removal of the honey from

[a] Browne, Analysis of Sugar Mixtures, J. Amer. Chem. Soc., 1906, *28*: 446.

the weighing dish without using more than 4 cc of water. The transference is best made by decanting as much as possible of the liquefied honey into the flask, then adding 2 cc of water to the dish to take up any adhering honey and again decanting. By using 1 cc more of the water in two successive washings and adding a few cubic centimeters of the absolute alcohol each time before decanting, the honey can be completely transferred without the necessity of using more water than the 4 cc. Absolute alcohol is used finally to rinse out the dish and is then added to the flask with continual agitation until the volume is completed to 100 cc. After shaking thoroughly the flask is allowed to stand until the dextrin has settled out upon the sides and bottom of the flask and the supernatant liquid has become perfectly clear (usually in twenty-four hours).

The clear solution is then decanted through a filter and the precipitated residue washed with 10 cc of cold 95 per cent alcohol to remove adhering liquid, the washings being also poured through the filter. The residue adhering to the flask and the particles which may have been caught upon the filter are dissolved in a little boiling distilled water and washed into a weighed platinum dish. The contents of the latter are then evaporated and dried in a water oven to constancy in weight. Should the amount of precipitate be considerable, it is necessary to dry upon sand in vacuo at 70°.

After determining the weight of the dried alcohol precipitate the latter is redissolved in water and made to a definite volume. The following dilutions were employed in making up the solutions:

Dilutions of dried alcohol precipitate.

Weight of precipitate.	Volume.
Grams.	*cc.*
0.0–0.5	50
0.5–1.0	100
1.0–1.5	150
1.5–2.0	200
2.0–2.5	250
2.5–3.0	300

The sugars were then determined in aliquots from the filtered solution of alcohol precipitate both before and after inversion. The total precipitate less invert sugar and sucrose gives the per cent of dextrin.[a]

While this method of estimating dextrin in honeys gives much more accurate results than the direct weighing of the alcohol precipitate, it can not be said in any way to give the true dextrin content of the honey, although it is believed that the figures obtained are a close approximation. A small amount of dextrin always escapes

[a] With honeydew honey, which gives a large amount of alcohol precipitate, it was found best to take only 4 grams of honey for analysis; in other respects the method of procedure is the same.

precipitation with alcohol; furthermore, no account is taken of the other ingredients which may be occluded in the alcohol precipitate other than the sugars, and no correction is made for the copper-reducing power of the honey dextrin itself. This latter factor, though apparently very small, might prove to be of some importance if much dextrin were present. Notwithstanding these limitations, however, the percentage of dextrin as determined by the method described has been found to have a decided value, especially when it is wished to compare honeys of different origins.

UNDETERMINED MATTER.

The undetermined matter of the honey (wax particles, pollen grains, higher alcohols, tannin, essential oils, combined acid, etc.) was estimated by difference.

FREE ACID.

The free acid in the honey, expressed as formic acid, was determined by titrating a weighed portion of the sample, after solution in distilled water, with tenth-normal sodium hydroxid, using phenolphthalein as indicator. It is customary to express the free acid in honey as formic, although other acids may, no doubt, be present. In soured or fermented honeys acetic acid is always formed.

TABULATION OF THE ANALYTICAL RESULTS.

In the tabulation of the analytical results the honeys were classified according to the floral origin. Ninety of the samples examined were labeled with the name of one definite flower, and these have been grouped together according to their botanical classification. Such a grouping has in some ways only a nominal value, since none of the honeys, as was shown by the microscopic examination of the pollen grains, was derived exclusively from the nectar of one kind of flower. In several cases the admixture of other kinds of nectars was indicated by the aroma. The botanical classification may be said, therefore, to represent simply the predominating kind of nectar gathered by the bees. Even with this limitation it will be noted that the chemical and physical constants of each class of honeys show a certain conformity to type.

The remaining ten honeys were labeled as being derived from mixed nectars, although several of these samples might be placed in the previous class with as much correctness as many of those marked unmixed. For general convenience it seemed more practicable to retain the nomenclature indicated by the bee keepers rather than to attempt a reclassification of the honeys based upon microscopic evidence as to the predominating kind of pollen.

Source and description of honeys analyzed.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	LEGUMINOSÆ.						
1	Alfalfa (*Medicago sativa* L.)	J. W. Lyell	Reno, Nev.	White	Solid	Spicy and pleasant	1
2	do	Wm. Stolley	Grand Island, Nebr.	Straw	do	do	2
3	do	P. R. Hobble	Dodge City, Kans.	White	do	do	3
4	do	I. D. Flory	Yerington, Nev.	do	do	do	4
5	do	H. W. Hamilton	Glendale, Ariz.	Dark brown	do	do	5
6	do	E. S. Lovesy	Salt Lake City, Utah	White	do	do	6
7	do	F. Rauchfuss	Denver, Colo.	do	do	do	7
8	do	E. Davis	Garden City, Kans.	do	do	do	8
9	White clover (*Trifolium repens* L.)	A. D. Woods	Lansing, Mich.	do	do	Mild, agreeable	9
10	do	M. V. Facy	Preston, Minn.	do	do	do	10
11	do	J. L. Gray	St. Cloud, Minn.	Light straw	Semisolid	do	11
12	do	E. S. Brown	Caribou, Me.	White	Solid	do	12
13	do	Joe Kurth	Mineral Point, Wis.	Light straw	Semisolid	do	13
14	do	J. Q. Smith	Lincoln, Ill.	White	Solid	do	14
15	do	Fred Muth (bottler) [a]	Ohio	do	do	do	15
16	do	H. S. Ferry	Mount Vernon, N. Y.	do	do	do	16
17	do	Mrs. Clara Evans	Lansing, Iowa	do	do	do	17
18	do	W. L. Hutchinson	Flint, Mich.	do	do	do	18
19	do	John Nebel & Son	High Hill, Mo.	Light straw	Semisolid	do	19
20	do	J. S. Gilfillan	Newark, Del.	do	do	do	20
21	do	E. D. Townsend	Remus, Mich.	White	Solid	do	21
22	do	C. S. Fuge	Oregon City, Oreg.	Light straw	Semisolid	do	22
23	do	J. E. Crane & Son	Middlebury, Vt.	White	Very slight	do	23
24	Alsike clover (*Trifolium hybridum* L.)	Experiment Station	Gallatin Valley, Mont.	do	Solid	Mild and pleasant	24
25	do	C. P. Jaeger	Portage, Wis.	do	do	Waxy aroma	25
26	do	H. Christensen	Puget, Wash.	do	Very slight	Very spicy	26

[a] Bottled in Cincinnati, Ohio.

Polarization and analysis of honeys.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	LEGUMINOSÆ.	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
1	Alfalfa	− 5.0	− 9.4	4.4	+15.3	−22.44	+ 5.39	27.83	14.84	72.65	10.01	0.07	0.65	1.78	0.08	69.60	
2	.....do	−16.0	−19.5	3.5	+ 4.6	−22.66	+ 3.52	26.18	20.47	76.30	1.45	.10	.39	1.29	.17	73.10	
3	.....do	−15.5	−18.6	3.1	+ 6.5	−23.65	+ 4.40	28.05	17.11	79.18	2.34	.05	.06	1.26	.06	75.85	
4	.....do	− 9.8	−13.3	3.5	+12.0	−21.01	+ 7.70	28.71	14.61	79.15	2.63	.07	.42	3.12	.05	75.83	
5	.....do	−17.5	−20.5	3.0	+ 5.0	−24.53	+ 3.85	28.38	17.37	79.10	.28	.16	.51	2.58	.14	75.78	Marked tannin reaction.
6	.....do	−10.8	−13.8	3.0	+10.6	−22.33	+ 5.28	27.61	15.91	77.35	4.12	.03	.57	2.02	.04	74.10	
7	.....do	− 7.3	−10.7	3.4	+13.0	−24.09	+ 4.40	28.49	15.75	74.33	9.37	.04	.06	.45	.05	71.21	
8	.....do	−11.0	−14.9	3.9	+10.0	−23.21	+ 5.50	28.71	16.42	77.16	5.15	.04	.04	1.19	.04	73.92	
	Average of alfalfa honeys.	**−11.6**	**−15.1**	**3.5**	**+ 9.63**	**−22.99**	**+ 5.00**	**27.99**	**16.56**	**76.90**	**4.42**	**.07**	**.34**	**1.71**	**.08**	**73.67**	**Levulose, 40.24; dextrose, 36.85.**
9	White clover	−10.5	−13.8	3.3	+10.7	−18.04	+ 8.80	26.84	17.02	78.15	0.29	0.11	1.32	3.11	0.06	74.86	
10	.....do	−11.4	−12.9	1.5	+11.3	−18.15	+ 9.13	27.28	15.93	76.32	2.92	.08	1.22	3.53	.08	73.10	
11	.....do	− 7.05	− 9.15	2.1	+14.1	−18.43	+ 8.80	27.23	16.80	70.57	7.01	.04	.25	5.33	.06	67.60	
12	.....do	−16.8	−18.2	1.4	+ 7.4	−22.99	+ 5.06	28.05	17.20	76.54	.00	.04	2.46	3.76	.05	73.33	
13	.....do	− 7.35	− 9.45	2.1	+15.9	−13.53	+13.75	27.28	14.54	76.02	1.54	.05	.40	7.45	.05	72.83	
14	.....do	− 9.80	−13.80	4.0	+11.05	−18.48	+ 8.14	26.62	17.67	76.60	.00	.04	.25	5.44	.05	73.38	
15	.....do	− 9.25	−16.40	7.15	+ 8.9	−20.3	+ 7.26	27.56	17.71	77.75	.00	.04	.07	4.43	.06	74.48	
16	.....do	−11.10	−14.45	3.35	+10.5	−18.92	+ 7.81	26.73	17.45	75.03	2.08	.04	.36	5.04	.05	71.88	
17	.....do	− 7.1	−10.45	3.35	+14.1	−12.93	+12.76	25.69	18.69	74.93	.69	.20	1.44	4.05	.05	71.78	
18	.....do	− 9.35	−15.75	6.40	+ 9.85	−19.25	+ 8.03	27.28	18.69	76.01	1.30	.05	.11	3.84	.05	72.82	
19	.....do	−11.60	−14.10	2.50	+10.2	−17.60	+ 8.91	26.51	19.96	73.69	.84	.06	.22	5.23	.09	70.60	
20	.....do	−13.80	−16.20	2.4	+ 8.9	−18.81	+ 7.92	26.73	20.24	73.36	1.54	.08	.44	4.34	.10	70.28	
21	.....do	− 9.40	−13.60	4.2	+11.2	−16.83	+10.78	27.61	17.10	76.45	.29	.08	.64	4.44	.05	73.24	
22	.....do	− 8.10	−10.90	2.8	+14.2	−14.30	+13.42	27.72	17.57	72.11	.91	.13	1.94	7.34	.10	69.08	
23	.....do	− 3.20	− 6.05	2.85	+16.4	−18.04	+ 8.14	26.18	18.10	70.32	7.09	.04	1.14	3.31	.05	67.37	
	Average of white clover honeys.	**− 9.72**	**−13.01**	**3.29**	**+11.65**	**−17.77**	**+ 9.25**	**27.02**	**17.64**	**74.92**	**1.77**	**.07**	**.82**	**4.78**	**.06**	**71.78**	**Levulose, 40.24; dextrose, 34.96.**
24	Alsike clover	− 2.40	−15.55	13.15	+10.4	−18.87	+ 9.13	28.00	12.42	78.37	1.71	0.06	0.46	6.98	0.04	75.08	
25	.....do	−10.60	−13.60	3.00	+11.1	−18.15	+ 9.9	28.05	16.93	77.18	.90	.08	.90	4.01	.06	73.94	
26	.....do	−10.55	−12.75	2.20	+11.95	−16.17	+10.12	26.29	18.91	74.72	1.47	.08	1.79	3.03	.06	71.58	
	Average of alsike clover honeys.	**− 7.85**	**−13.97**	**6.12**	**+11.15**	**−17.73**	**+ 9.72**	**27.45**	**16.09**	**76.76**	**1.36**	**.07**	**1.05**	**4.67**	**.05**	**73.53**	**Levulose, 40.95; dextrose, 36.06.**

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	LEGUMINOSÆ—Continued.						
27	Sweet clover (*Melilotus alba* Lam.)	Fred Muth (bottler) [a]	Alabama	White	Solid	Mild, pleasant	27
28	do	J. W. Lyell	Reno, Nev	Straw	do	do	28
29	do	E. A. Simmons	Spring Hill, Ala	Dark straw	Semisolid	Very spicy	29
30	do	Wm. Stolley	Grand Island, Nebr	White	Solid	Spicy	30
31	Cat claw (*Acacia wrightii* Benth.)	W. Atchley	Beeville, Tex	Straw	do	Mild	31
32	do	Hyde Bee Company	Floresville, Tex	White	do	do	32
33	Mesquit (*Prosopis* sp.)	Wm. Lossing	Phoenix, Ariz	Straw	do	Mild, pleasant	33
34	do	Hyde Bee Company	Floresville, Tex	do	do	Mild	34
35	Algarroba (*Prosopis juliflora* (Swz.) DC.)	Sandwich Islands Honey Company.	Honolulu, Hawaii	White	do	do	35
36	Locust (*Gleditsia triacanthos* L.)	Fred Muth (bottler) [a]	Ohio	do	Liquid	Very mild	36
37	Yellow wood (*Cladrastis lutea* (Michx.) Koch)	S. M. Campbell	Mountainburg, Ark	Dark straw	Very slight	Pungent, peculiar	37

[a] Bottled in Cincinnati, Ohio.

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	LEGUMINOSÆ—Continued.	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
27	Sweet clover	−16.00	−17.45	1.45	+ 6.6	−22.00	+ 5.06	27.06	17.91	76.70	2.15	0.09	0.25	2.90	0.08	73.48	
28	.....do	−10.30	−14.50	4.20	+10.7	−23.54	+ 5.61	29.15	14.44	78.62	1.09	.06	.38	5.41	.08	75.32	
29	... .do	− 9.80	−17.50	7.70	+ 6.2	−20.79	+ 5.72	26.51	20.56	73.75	1.86	.27	.90	2.66	.19	70.65	
30	.....do	−12.45	−21.00	8.55	+ 3.7	−25.08	+ 2.42	27.50	17.04	75.72	3.86	.08	.26	3.04	.14	72.54	
	Average of sweet clover honeys.	**−12.14**	**−17.61**	**5.47**	**+ 6.8**	**−22.85**	**+ 4.70**	**27.55**	**17.49**	**76.20**	**2.24**	**.12**	**.45**	**3.50**	**.12**	**73.00**	**Levulose, 39.59; dextrose, 36.78.**
31	Cat claw	−14.75	−17.35	2.60	+ 7.9	−21.01	+ 5.72	26.73	17.53	78.22	3.00	0.09	0.27	0.89	0.06	74.94	
32	.....do	−14.95	−16.80	1.85	+ 8.2	−21.12	+ 7.04	28.16	15.54	79.50	1.54	.11	.38	2.93	.05	76.16	
	Average of cat claw honeys.	**−14.85**	**−17.08**	**2.23**	**+ 8.05**	**−21.07**	**+ 6.38**	**27.45**	**16.53**	**78.86**	**2.27**	**.10**	**.33**	**1.91**	**.06**	**75.55**	**Levulose, 40.81; dextrose, 38.21.**
33	Mesquit	−17.00	−20.50	3.5	+ 5.2	−23.76	+ 3.96	27.72	15.66	79.94	1.12	0.14	0.47	2.67	0.07	76.58	
34	.....do	−17.60	−20.30	2.7	+ 5.4	−23.65	+ 3.52	27.17	15.39	79.90	1.37	.08	.25	3.01	.06	76.54	Slight tannin reaction.
35	Mesquit (algarroba)	−17.80	−22.00	4.2	+ 2.7	−27.61	+ 1.00	28.61	17.83	76.84	3.58	.34	.14	1.27	.05	73.61	High in chlorids.
	Average of mesquit honeys.	**−17.47**	**−20.93**	**3.46**	**+ 4.45**	**−25.01**	**+ 2.83**	**27.84**	**16.29**	**78.89**	**2.02**	**.19**	**.29**	**2.32**	**.06**	**75.58**	**Levulose, 41.03; dextrose, 38.04.**
36	Locust	−18.5	−21.4	2.9	+ 7.4	−26.07	+ 5.06	31.13	15.38	75.34	1.24	0.08	2.13	5.83	0.06	72.18	
37	Yellow wood	− 4.9	− 7.0	2.1	+15.0	−10.56	+14.74	25.30	18.12	71.51	.19	.39	4.10	5.69	.15	68.50	Tannin reaction.
	Average of Leguminosæ (37 samples).	**−11.25**	**−14.96**	**3.71**	**+ 9.84**	**−20.24**	**+ 7.23**	**27.47**	**17.05**	**76.11**	**2.35**	**.10**	**.84**	**3.55**	**.07**	**72.90**	**Levulose, 40.35; dextrose, 35.98.**

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	COMPOSITÆ.						
38	Dandelion (*Taraxacum taraxacum* (L.) Karst)	J. W. Lyell	Reno, Nev	White	Solid	Sharp	38
39	....do	E. S. Brown	Caribou, Me	Straw	Liquid	Very pleasant; odor of fruit bloom.	39
40	Golden-rod (*Solidago* sp.)	Mose Baker	Granton, Wis	....do	Very liquid	Sour, slightly fermented	40
41	....do	E. S. Brown	Caribou, Me	Light straw	Semisolid	Strong	41
42	....do	F. G. Herman	Englewood, N. J	Dark brown	....do	Rank	42
43	Arrow weed (*Pluchea sericea* (Nutt.) Coville)	Wm. Lossing	Phoenix, Ariz	White	Solid	Mild	43
44	Wild aster (*Aster* sp.)	F. G. Herman	Englewood, N. J	Brown	....do	Pungent	44
45	Spanish needle (*Bidens* sp.)	Jas. Nebel & Son	High Hill, Mo	....do	Liquid	Strong, aromatic	45
	ROSACEÆ.						
46	Apple (*Pyrus malus* L.)	J. S. Whittemore	Leicester, Mass	White	Solid	Fragrant	46
47	....do	S. H. Chency	Worcester, Mass	Light straw	....do	....do	47
48	Raspberry (*Rubus* sp.)	O. B. Griffin	Caribou, Me	....do	Slight	Mild and pleasant	48
49	Wild red raspberry (*Rubus* sp.)	M. Baker	Granton, Wis	White	Solid	....do	49

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	COMPOSITÆ.	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	° *V.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	
38	Dandelion	− 9.2	−12.0	2.8	+12.6	−20.13	+ 7.81	27.94	14.53	77.48	4.66	0.21	0.45	2.67	0.05	74.23	
39	.....do	−11.2	−12.8	1.6	+13.4	−17.71	+11.22	28.93	14.55	76.21	1.57	.11	2.01	5.55	.05	73.01	
	Average of dandelion honeys.	**−10.2**	**−12.4**	**2.2**	**+13.0**	**−18.92**	**+ 9.51**	**28.43**	**14.54**	**76.84**	**3.12**	**.16**	**1.23**	**4.11**	**.05**	**73.61**	**Levulose, 41.50; dextrose, 35.64.**
40	Golden-rod	− 7.8	− 9.5	1.7	+11.2	−12.54	+10.78	23.32	25.90	67.81	1.67	0.15	2.28	2.19	0.21	64.96	
41	.....do	− 9.5	−11.1	1.6	+13.0	−15.62	+11.33	26.95	16.20	74.59	1.06	.09	1.56	6.50	.06	71.75	
42	.....do	−14.8	−16.4	1.6	+ 8.4	−21.12	+ 5.94	27.06	17.53	73.65	2.30	.24	2.71	3.57	.06	70.56	Tannin reaction.
	Average of goldenrod honeys.	**−10.70**	**−12.33**	**1.63**	**+10.87**	**−16.43**	**+ 9.35**	**25.78**	**19.88**	**72.02**	**1.68**	**.16**	**2.18**	**4.08**	**.11**	**69.09**	**Levulose, 37.85; dextrose, 34.45.**
43	Arrow weed	−14.0	−20.3	6.3	+ 6.9	−23.32	+ 4.62	27.94	12.72	83.36	2.08	0.10	1.70	0.04	0.05	79.86	
44	Wild aster	−16.5	−21.4	4.9	+ 5.8	−22.44	+ 5.06	27.50	19.43	76.00	.64	.25	1.42	2.26	.15	72.81	
45	Spanish needle	−15.4	−18.6	3.2	+ 9.6	−20.46	+ 9.35	29.81	19.18	69.58	1.23	.05	3.45	6.51	.06	66.66	
	Average of Compositæ (8 samples).	**−12.30**	**−15.26**	**2.96**	**+10.11**	**−19.17**	**+ 8.26**	**27.43**	**17.51**	**74.84**	**1.90**	**.15**	**1.95**	**3.65**	**.09**	**71.73**	**Levulose, 41.31; dextrose, 33.93.**
	ROSACEÆ.																
46	Apple	− 1.15	− 8.90	7.75	+16.7	−13.70	+12.65	26.35	16.78	73.22	2.72	0.04	0.37	6.87	0.05	70.15	
47	.....do	− 4.25	− 8.20	3.95	+17.3	−13.75	+12.87	26.62	14.55	73.11	4.66	.13	.40	7.15	.05	70.04	
	Average of apple honeys.	**−2.70**	**− 8.55**	**5.85**	**+17.0**	**−13.73**	**+12.76**	**26.49**	**15.67**	**73.16**	**3.69**	**.08**	**.39**	**7.01**	**.05**	**70.10**	**Levulose, 42.00; dextrose, 31.67.**
48	Raspberry	−15.9	−19.4	3.5	+ 6.3	−23.76	+ 4.62	28.38	16.26	76.52	1.88	0.05	0.80	4.49	0.06	73.31	
49	Wild red raspberry	−15.5	−18.3	2.8	+ 7.0	−22.66	+ 5.50	28.16	19.90	72.53	.95	.05	.32	6.25	.05	69.48	
	Average of raspberry honeys.	**−15.7**	**−18.85**	**3.15**	**+ 6.65**	**−23.21**	**+ 5.06**	**28.27**	**18.08**	**74.52**	**1.42**	**.05**	**.56**	**5.37**	**.06**	**71.40**	**Levulose, 41.34; dextrose, 33.57.**
	Average of Rosaceæ (4 samples).	**− 9.20**	**−13.70**	**4.50**	**+11.83**	**−18.47**	**+ 8.91**	**27.38**	**16.87**	**73.85**	**2.55**	**0.06**	**0.47**	**6.20**	**0.05**	**70.75**	**Levulose, 41.65; dextrose, 32.64.**

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	POLYGONACEÆ.						
50	Buckwheat (*Fagopyrum fagopyrum* (L.) Karst)	F. W. Wilcox	Manston, Wis	Very dark brown	Solid	Rank	50
51	do	E. D. Townsend	Remus, Mich	do	do	do	51
52	Wild buckwheat (*Eriogonum* sp.)	F. D. Lowe	Bakersfield, Cal	Light straw	do	Rather strong	52
53	do	H. E. Wilder	Riverside, Cal	Dark straw	Liquid	Very fragrant and pleasant.	53
54	Heartsease (*Polygonum persicaria* L.)	F. G. Herman	Englewood, N. J	Very dark	do	Spicy	54
	MENTHACEÆ.						
55	Wild pennyroyal (*Mentha arvensis* L.)	O. O. Poppleton	Stuart, Fla	Straw	Solid	Strong minty odor	55
56	Sage (*Salvia officinalis* L.)	J. F. McIntyre	Ventura, Cal	Very light straw	Liquid	Mildly pungent	56
	MALVACEÆ.						
57	Cotton (*Gossypium herbaceum* L.)	E. A. Simmons	Spring Hill, Ala	Straw	Solid	Spicy, fragrant	57
58	do	D. W. Switzer	Roebuck, S. C	White	Very hard	do	58
59	do	J. B. Alexander	Lecont, Ark	Brown	Semisolid	do	59

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	POLYGONACEÆ.	° V.	° V.	° V.	° V.	° V	° V.	° V.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
50	Buckwheat	−14.7	−17.4	2.7	+ 8.0	−19.80	+ 6.05	25.85	18.11	77.48	0.00	0.07	1.04	3.30	0.22	74.23	Slight tannin reaction.
51	....do	−14.5	−16.2	1.7	+ 8.4	−21.01	+ 5.83	26.84	18.96	76.21	.06	.11	1.41	3.25	.20	73.01	Strong tannin reaction.
	Average of buckwheat honeys.	**−14.6**	**−16.8**	**2.2**	**+ 8.2**	**−20.41**	**+ 5.94**	**26.35**	**18.54**	**76.85**	**.03**	**.09**	**1.22**	**3.27**	**.21**	**73.62**	**Levulose, 40.29; dextrose, 36.75.**
52	Wild buckwheat	−12.6	−18.0	5.4	+ 6.0	−22.44	+ 3.74	26.18	17.92	78.89	0.60	0.08	0.34	2.17	0.10	75.58	Tannin reaction.
53	....do	−16.4	−18.9	2.5	+ 8.0	−20.90	+ 7.26	28.16	17.96	73.98	.00	.12	1.91	6.03	.14	70.87	
	Average of wild buckwheat honeys.	**−14.5**	**−18.5**	**4.0**	**+ 7.0**	**−21.67**	**+5.50**	**27.17**	**17.94**	**76.44**	**.30**	**.10**	**1.13**	**4.09**	**.12**	**73.23**	**Levulose, 41.36; dextrose, 35.39.**
54	Heartsease	− 7.6	− 9.1	1.5	+12.2	−13.64	+11.00	24.64	19.96	69.61	3.09	0.48	4.75	2.11	0.17	66.99	Slight tannin reaction.
	Average of Polygonaceæ (5 samples).	**−13.16**	**−15.92**	**2.76**	**+ 8.52**	**−19.56**	**+ 6.78**	**26.34**	**18.58**	**75.23**	**0.75**	**0.17**	**1.89**	**3.38**	**0.16**	**72.08**	**Levulose, 39.73; dextrose, 35.73.**
	MENTHACEÆ.																
55	Wild pennyroyal	+20.4	+17.0	3.4	+35.8	+14.96	+34.98	20.02	16.44	71.69	0.61	0.29	6.02	4.95	0.05	68.68	Levulose, 24.35; dextrose, 46.40.
56	Sage	−18.1	−20.8	2.7	+ 5.8	−26.62	+ 3.08	29.70	16.43	73.97	3.39	.07	.62	5.52	.06	70.86	
	MALVACEÆ.																
57	Cotton	−12.5	−16.8	4.3	+ 7.0	−20.02	+ 7.04	27.06	18.91	74.70	1.64	0.13	0.37	4.25	0.12	71.56	
a58	.....do	− 2.3	− 5.0	2.7	+15.0	− 7.48	+13.75	21.23	17.81	80.69	.48	.14	.40	.48	.20	77.30	Levulose, 32.85; dextrose, 40.80.
59	.....do	−16.5	−18.2	1.7	+ 6.6	−22.00	+ 5.06	27.06	17.79	76.15	1.13	.28	1.83	2.82	.19	72.95	
	Average of cotton honeys.	**−14.5**	**−17.5**	**3.0**	**+ 6.8**	**−21.01**	**+ 6.05**	**27.06**	**18.35**	**75.43**	**1.38**	**.21**	**1.10**	**3.53**	**.15**	**72.26**	**Levulose, 39.42; dextrose, 36.19.**

[a] Abnormal; excluded from average on account of leakage of liquid portion.

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	MORACEÆ.						
60	Hop vine (*Humulus lupulus* L.)	Miss O. P. Hendrix	Satartia, Miss	Dark brown	Semisolid	Mild aromatic	60
	CUCURBITACEÆ.						
61	Melon (*Cucurbita* sp.)	Louis Werner	Edwardsville, Ill	Dark brown	Liquid	Rather sharp	61
	CACTACEÆ.						
62	Prickly pear (*Opuntia* sp.)	Hawaiian Agricultural Experiment Station.	Hanapepe, Kauai, Hawaiian Islands.	White	Semisolid	Mild	62
	TILIACEÆ.						
63	Basswood (*Tilia* sp.)	S. M. Campbell	Mountainburg, Ark	Dark straw	Semisolid	Rank	63
64	do	F. A. Sampson	Ronceverte, W. Va	do	do	Sharp aromatic	64
65	do	Miss O. P. Hendrix	Satartia, Miss	White	Solid	Mild aromatic	65
66	do	J. L. Gray	St. Cloud, Minn	do	do	Strong aromatic	66
67	do	W. L. Hutchinson	Flint, Mich	do	do	do	67
68	do	Joe Kurth	Mineral Point, Wis	do	do	do	68
	PHŒNICACEÆ.						
69	Cabbage palm (*Sabal palmetto* (Walt.) R. & S.)	H. B. Henecke	Titusville, Fla	Straw	Solid	Mild	69
70	Sawpalmetto (*Serenoa serrulata* (Michx.) Hook)	H. E. Hill	Fort Pierce, Fla	Dark straw	Semisolid	Spicy and pleasant	70
71	Palmetto-berry dew	H. B. Henecke	Titusville, Fla	Dark brown	Solid	Rank	71

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	MORACEÆ.	°V.	°V.	°V.	°V.	°V.	°V.	°V.	P. ct.	P. ct.	P. ct.	P. ct	P. ct.	P. ct.	P. ct.	P. ct.	
60	Hop vine	−10.9	−12.6	1.7	+10.8	−16.83	+ 9.68	26.51	16.55	73.48	2.21	0.22	2.34	5.20	0.15	70.39	Very strong tannin reaction.
	CUCURBITACEÆ.																
61	Melon	−11.4	−14.4	3.0	+ 9.3	−18.70	+ 8.58	27.28	19.23	72.05	1.89	.24	2.55	4.04	.16	69.02	
	CACTACEÆ.																
62	Prickly pear	−11.9	−15.5	3.6	+ 9.1	−17.93	+ 7.81	25.74	20.51	73.72	3.19	.52	1.89	.17	.11	70.62	
	TILIACEÆ.																
63	Basswood	+ 3.7	− 0.3	4.0	+23.7	− 1.32	+23.21	24.53	17.47	69.85	0.69	0.35	7.58	4.06	0.13	66.92	Slight tannin reaction.
64	do	− 9.3	−13.7	4.4	+ 9.7	−16.83	+ 8.58	25.41	20.25	73.25	.00	.22	2.07	4.21	.18	70.17	Do.
65	do	− 4.5	− 7.8	3.3	+15.1	−12.32	+13.31	25.63	16.47	78.55	.07	.15	1.50	3.26	.10	75.24	
66	do	− 9.2	−12.6	3.4	+11.0	−16.39	+ 9.57	25.96	18.03	77.20	.11	.11	1.55	3.00	.06	73.96	
67	do	− 7.9	−11.0	3.1	+14.2	−14.41	+12.65	27.06	16.64	76.74	1.43	.17	2.19	2.83	.05	73.52	
68	do	− 3.8	− 8.0	4.2	+16.6	−12.21	+14.41	26.62	15.66	75.24	2.03	.19	3.53	3.35	.05	72.07	
	Average of basswood honeys.	**− 5.2**	**− 8.9**	**3.7**	**+15.05**	**−12.25**	**+13.62**	**25.87**	**17.42**	**75.14**	**.72**	**.20**	**3.07**	**3.45**	**.10**	**71.98**	**Levulose, 39.27; dextrose, 36.05.**
	PHŒNICACEÆ.																
69	Cabbage palm	−18.0	−21.4	3.4	+ 3.6	−25.19	+ 2.53	27.72	18.56	79.35	0.35	0.18	0.52	1.04	0.07	76.02	
70	Saw palmetto	−14.2	−16.8	2.6	+12.0	−20.02	+ 7.81	27.83	19.22	73.63	.69	.32	2.14	4.00	.10	70.54	Very slight tannin reaction.
71	Palmetto-berry dew	−13.2	−17.2	4.0	+ 6.2	−21.23	+ 4.40	25.63	18.34	73.51	1.92	.69	3.05	2.49	.25	70.42	Marked tannin reaction.
	Average of Phœnicaceæ.	**−15.13**	**−18.46**	**3.33**	**+ 7.27**	**−22.15**	**+ 4.91**	**27.06**	**18.71**	**75.50**	**.99**	**.40**	**1.90**	**2.50**	**.14**	**72.33**	**Levulose, 41.73; dextrose, 34.15.**

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	SALICACEÆ.						
72	Poplar (*Populus* sp.)	D. W. Switzer	Roebuck, S. C.	Dark brown	Liquid	Molasses-like	72
73	Willow (*Salix* sp.)	B. Davenport	Berlin, Wis.	Brown	do	Very aromatic and spicy	73
	ERICACEÆ.						
74	Laurel (*Kalmia latifolia* L.)	H. B. Henecke	Titusville, Fla.	Brown	Very slight	Mild aromatic	74
75	White alder (*Clethra alnifolia* L.)	A. C. Miller	Barrington, R. I.	Straw	do	do	75
	RUTACEÆ.						
76	Orange (*Citrus aurantium* L.)	H. E. Wilder	Riverside, Cal.	Straw	Solid	Very pleasant	76
	ANACARDIACEÆ.						
77	Sumac (*Rhus glabra* L.)	J. B. Alexander	Leeont, Ark.	Dark straw	Semisolid	Aromatic	77
78	do	S. M. Campbell	Mountainburg, Ark.	Very dark brown.	Liquid	Very rank; astringent	78
79	do	J. F. Hairston	Salina, Ind. T.	Straw	do	Sharp	79

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	SALICACEÆ.	°V.	°V.	°V	°V.	°V.	°V.	°V.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
72	Poplar	+ 6.7	+ 3.6	3.1	.....	− 2.53	+20.9	23.43	17.02	65.80	3.10	0.76	10.19	3.13	0.19	63.04	Strong tannin reaction.
73	Willow	−11.5	−12.9	1.4	+10.8	−15.62	+10.12	25.74	19.11	71.47	.95	.35	2.75	5.37	.07	68.46	Do.
	ERICACEÆ.																
74	Laurel	−16.1	−18.8	2.7	+ 5.3	−22.44	+ 4.62	27.06	18.81	75.57	1.04	0.27	0.98	3.33	0.11	72.40	Very slight tannin reaction.
75	White alder	− 8.6	−11.05	2.45	+12.8	−14.52	+11.17	25.69	20.34	68.24	4.00	.19	3.48	3.75	.15	65.38	
	Average of Ericaceæ	**−12.35**	**−14.93**	**2.58**	**+ 9.05**	**−18.48**	**+ 7.90**	**26.38**	**19.58**	**71.90**	**2.52**	**.23**	**2.23**	**3.54**	**.13**	**68.89**	**Levulose, 39.04; dextrose, 33.17.**
	RUTACEÆ.																
76	Orange	−11.7	−15.5	3.8	+ 8.8	−19.25	+ 6.6	25.85	16.99	77.57	0.60	0.08	0.45	4.31	0.08	74.31	
	ANACARDIACEÆ.																
77	Sumac	−11.1	−13.8	2.7	+ 8.5	−17.60	+ 7.81	25.41	19.25	73.73	0.39	0.21	1.66	4.76	0.15	70.63	Slight tannin reaction.
78	.....do	− 6.6	− 9.1	2.5	+14.5	−12.98	+12.32	25.30	18.17	68.61	2.01	.90	6.42	3.89	.18	65.73	Very strong tannin reaction.
79	.....do	− 4.6	− 8.5	3.9	+14.6	−11.44	+14.41	25.85	19.11	71.00	.36	.22	2.63	6.68	.09	68.02	
	Average of sumac honeys.	**− 7.43**	**−10.47**	**3.03**	**+12.53**	**−14.01**	**+11.51**	**25.52**	**18.85**	**71.11**	**.92**	**.44**	**3.57**	**5.11**	**.14**	**68.13**	**Levulose, 37.61; dextrose, 33.72.**

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Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	MYRTACEÆ.						
80	Mangrove (*Rhizophora mangle* L.)	O. O. Poppleton	Stuart, Fla	Light straw	Solid	Pleasant; aromatic	80
81	do	Fred Muth (bottler) [a]	Florida	Straw	do	Mild	81
	CORNACEÆ.						
82	Tupelo (*Nyssa aquatica* L.)	A. B. Maschant	Apalachicola, Fla	Straw	Liquid	Very aromatic	82
83	do	Fred Muth (bottler) [a]	Florida	do	do	Mild	83
	MAGNOLIACEÆ.						
84	Whitewood (*Liriodendron tulipifera* L.)	F. G. Herman	Englewood, N. J	Very dark brown	Slight	Rather rank	84
	JUGLANDACEÆ.						
85	Hickory (*Hicoria* sp.)	S. M. Campbell	Mountainburg, Ark	Brown	Liquid	Strong; molasses-like	85
	FAGACEÆ.						
86	White oak (*Quercus alba* L.)	S. M. Campbell	Mountainburg, Ark	Brown	Liquid	Strong; molasses-like	86
	MYRTACEÆ (LEPTOSPERMEÆ).						
87	Blue gum (*Eucalyptus globulus* Labill.)	Hawaiian Agricultural Experiment Station.	Kaulaʻpuu, Molakai, Hawaiian Islands.	White	Solid	Mild	87
88	Ohia Lehua (*Metrosideros villosa* Smith)	do	Poholua, Molakai, Hawaiian Islands.	Pale straw	Semisolid	Molasses-like	88

[a] Bottled in Cincinnati, Ohio.

Polarization and analysis of honeys—Continued.

[For description of each sample see p receding page.]

No.	Source of honey according to flower.	Polarization. Direct. Immediate, 20° C.	Direct. Constant, 20° C.	Direct. Birotation.	Direct. 87° C.	Invert. 20° C.	Invert. 87° C.	Invert. Difference.	Complete analysis. Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.	Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	MYRTACEÆ.	°V.	°V.	°V.	°V.	°V.	°V.	°V.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
80	Mangrove	−21.1	−24.8	3.7	+ 0.5	−27.94	− 0.66	27.28	19.53	77.04	1.14	0.16	0.29	1.84	0.07	73.80	
81	do	−17.6	−20.8	3.2	+ 5.3	−24.42	+ 2.86	27.28	18.83	75.94	2.33	.24	.82	1.84	.08	72.75	
	Average of mangrove honeys.	**−19.4**	**−22.8**	**3.4**	**+ 2.9**	**−26.18**	**+ 1.10**	**27.28**	**19.18**	**76.49**	**1.73**	**.20**	**.56**	**1.84**	**.08**	**73.28**	**Levulose, 41.47; dextrose, 35.33.**
	CORNACEÆ.																
82	Tupelo	−21.9	−24.6	2.7	+ 6.2	−29.26	+ 4.29	33.55	16.29	72.09	4.36	0.07	2.69	4.50	0.05	69.06	
83	do	−20.6	−23.4	2.8	+ 5.9	−27.50	+ 4.62	32.12	18.38	72.40	1.65	.08	1.47	6.02	.06	69.36	
	Average of tupelo honeys.	**−21.25**	**−24.0**	**2.75**	**+ 6.05**	**−28.38**	**+ 4.46**	**32.84**	**17.34**	**72.24**	**3.01**	**.07**	**2.08**	**5.26**	**.06**	**69.21**	**Levulose, 48.61; dextrose, 24.73.**
	MAGNOLIACEÆ.																
84	Whitewood	− 3.1	− 4.9	1.8	+17.8	− 9.68	+15.4	25.08	17.47	69.02	2.72	0.51	5.59	4.69	0.16	66.11	Slight tannin reaction.
	JUGLANDACEÆ.																
85	Hickory	+11.7	+ 7.8	3.9	+28.5	+ 3.41	+26.62	23.21	16.05	65.89	2.76	.78	12.95	1.57	.12	63.12	Slight tannin reaction.
	FAGACEÆ.																
86	White oak	+20.9	+11.0	9.9	+32.3	+ 5.17	+28.60	23.43	13.56	65.87	4.31	.79	10.49	4.98	.08	63.11	
	MYRTACEÆ (Leptospermeæ).																
87	Blue gum	−18.8	−22.6	3.8	+ 2.3	−26.84	+ 6.44	27.28	16.94	79.09	2.04	0.38	0.21	1.34	0.06	75.76	High in chlorids.
88	Ohia Lehua	−12.4	−15.9	3.5	+ 7.0	−18.70	+ 6.27	24.97	20.00	75.57	1.03	.21	.46	2.73	.15	72.40	Very slight tannin reaction; high in chlorids.
	Average of Leptospermeæ.	**−15.6**	**−19.25**	**3.65**	**+ 4.65**	**−22.77**	**+ 3.36**	**26.13**	**18.47**	**77.33**	**1.53**	**.30**	**.34**	**2.03**	**.11**	**74.08**	**Levulose, 38.65; dextrose, 38.72.**

Source and description of honeys analyzed—Continued.

No.	Source of honey according to flower.	Name of producer or bottler.	Locality.	Physical characteristics.			No.
				Color.	Granulation.	Odor and flavor.	
	MIXED FLOWERS.						
89	Fall flowers	M. V. Facey	Preston, Minn.	Dark brown	Liquid	Pleasant	89
90	do	Mrs. Clara Evans	Lansing, Iowa	Straw	Slight	Pleasant and spicy	90
91	Fruit bloom	E. S. Brown	Caribou, Me	White	Liquid	Rather pungent	91
92	Basswood and fall bloom	M. V. Facey	Preston, Minn.	Straw	Semisolid	Aromatic	92
93	Alfalfa, catnip, and cleome	Wm. Stolley	Grand Island, Nebr.	Dark straw	Liquid	Rather strong	93
94	"Seaweed and blue flower"	Hawaiian Agricultural Experiment Station.	Lemahua, Kauai, Hawaiian Islands.	Pale straw	do	Molasses-like	94
95	(*Verbena bonariensis, Ipomœa, Thevetia nereifolia, Malvastrum tricuspidatum*, lantana, guava, and keawe).	do	Tantalus 350 feet, Honolulu, Hawaiian Islands.	Straw	Semisolid	Mild; agreeable	95
	HAWAIIAN HONEYDEW AND BLENDS.						
96	Hawaiian sugar cane honeydew	Garden Island Honey Co.	Hawaiian Islands	Very dark	Liquid	Strong; molasses-like	96
97	Honeydew and flowers of lantana, *Waltheria americana, Heteropogon contortus, Verbena bonariensis*, and guava.	Hawaiian Agricultural Experiment Station.	Kipapa Gulch, Oahu, Hawaiian Islands.	Dark straw	Trace	Rather strong; molasses-like.	97
98	Honeydew, thimbleberry, and forest flowers	do	Mt. View, Hawaiian Islands.	do	Very slight	Minty; strong molasses-like.	98
99	Honeydew, *Prosopis juliflora* and weeds	do	Mahinauli, Kauai, Hawaiian Islands.	Straw	do	Slight; molasses-like	99
100	do	do	Waimea, Kauai, Hawaiian Islands.	Pale straw	do	Mild	100

Polarization and analysis of honeys—Continued.

[For description of each sample see preceding page.]

No.	Source of honey according to flower.	Polarization.							Complete analysis.						Free acid as formic.	Reducing sugars as dextrose.	Remarks.
		Direct.				Invert.											
		Immediate, 20° C.	Constant 20° C.	Birotation.	87° C.	20° C.	87° C.	Difference.	Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.			
	MIXED FLOWERS.	°V.	°V.	°V.	°V.	°V.	°V.	°V.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
89	Fall flowers	− 4.20	− 5.80	1.60	+15.8	− 9.79	+13.86	23.65	26.88	62.23	2.07	0.35	3.26	5.21	0.07	59.61	Slight tannin reaction.
90	.....do	− 4.90	− 7.60	2.70	+16.8	−11.66	+15.18	26.84	17.22	72.99	1.35	.25	3.66	4.53	.08	69.92	Very slight tannin reaction.
91	Fruit bloom	−13.00	−16.40	3.40	+10.4	−23.21	+ 6.05	29.26	15.82	76.40	2.66	.03	.63	4.46	.06	73.19	
92	Basswood and fall bloom.	+ 0.8	−10.8	11.6	+12.6	−14.74	+11.66	26.40	18.44	74.47	1.08	.18	2.87	2.96	.11	71.35	Do.
93	Alfalfa, catnip, and cleome	−13.8	−15.9	2.1	+ 8.7	−20.02	+ 6.82	26.84	18.93	76.85	.05	.09	1.12	2.96	.11	73.62	Slight tannin reaction.
94	"Sea weed and blue flower."	− 4.8	− 8.2	3.4	+14.6	−10.34	+13.20	23.54	20.59	70.33	1.56	.79	3.60	3.13	.15	67.38	
95	*Verbena bonariensis, Ipomæa, Thevetia nereifolia, Malvastrum tricuspidatum,* lantana, guava, and keawe.	−17.6	−20.0	2.4	+ 4.1	−26.07	+ 1.54	27.61	17.82	77.62	2.81	.32	.29	1.14	.08	74.36	
	HAWAIIAN HONEYDEW AND BLENDS.																
96	Hawaiian sugar-cane honeydew.	+24.9	+17.75	7.15	.....	+13.53	+34.76	21.23	15.46	64.84	5.27	1.29	10.01	3.13	.15	62.12	High in chlorids.
97	Honeydew and flowers of lantana, *Waltheria americana, Heteropogon contortus, Verbena bonariensis,* and guava.	+ 9.8	+ 3.6	6.2	.....	+ 1.87	+23.65	21.78	16.29	67.81	2.57	1.02	9.65	2.66	.14	64.96	Do.
98	Honeydew, thimbleberry, and forest flowers.	+ 9.0	+ 5.3	3.7	.....	+ 1.87	+23.43	21.56	17.80	66.85	2.41	.80	8.62	3.52	.13	64.04	Do. Slight tannin reaction.
99	Honeydew, *Prosopis juliflora,* and weeds.	− 6.8	−11.4	4.6	.....	−14.08	+10.34	24.42	16.19	75.97	.36	.57	3.57	3.34	.10	72.77	High in chlorids.
100	.....do	−10.6	−15.1	4.5	.....	−18.15	+ 7.81	25.96	15.88	76.55	1.14	.48	1.77	4.18	.07	73.33	Do.

Polarization and analysis of honeys—Continued.

GENERAL AVERAGES.

Source of honey according to flower.	Polarization.							Complete analysis.						Free acid as formic.	Reducing sugars as dextrose.	Remarks.
	Direct.				Invert.											
	Immediate, 20° C.	Constant, 20° C.	Birotation.	87° C.	20° C.	87° C.	Difference.	Water.	Invert sugar.	Sucrose.	Ash.	Dextrin.	Undetermined.			
	° V.	° V.	° V.	° V.	° V.	° V.	° V.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	
Levorotatory honeys (92 samples).	−11.24	−14.73	3.49	+10.15	−19.16	+ 7.91	27.07	17.70	74.98	1.90	0.18	1.51	3.73	0.08	71.08	Levulose, 40.50; dextrose, 34.02.
Dextrorotatory honeys (7 samples).	+14.77	+ 9.43	5.34	+32.20	+ 5.47	+27.56	22.09	16.09	66.96	3.01	.81	9.70	3.43	.12	64.15	
All honeys (99 samples)	− 9.41	−13.02	3.61	+10.81	−17.41	+ 9.30	26.71	17.59	74.41	1.98	.23	2.09	3.70	.09	70.59	

EXTREMES.

Levorotatory honeys:																
Maximum	−21.9	−24.8	11.6	+23.7	−29.26	+23.21	33.55	26.88	83.36	10.01	0.90	7.58	7.45	0.25	79.86	
Minimum	+ 3.7	− 0.3	1.4	+ 0.5	− 1.32	− 0.66	23.32	12.42	62.23	0.00	.03	.04	.04	.04	59.61	
Dextrorotatory honeys:																
Maximum	+24.9	+17.75	7.15	+35.8	+14.96	+34.98	23.43	17.80	71.69	5.28	1.29	12.95	4.95	.19	68.68	
Minimum	+ 6.7	+ 3.6	3.1	+28.5	− 2.53	+20.90	20.02	13.56	64.84	.61	.29	6.02	1.57	.05	62.12	

Average composition of honeys by Lehman and Stadlinger (17 samples). [a]

Polarization (° Ventzke).[b]		Water.	Invert sugar.	Sucrose.	Ash.	Undetermined.	Free acid.
Direct.	Invert.						
−13.82	−18.44	19.30	73.45	3.09	0.09	4.07	0.07

[a] Zts. Nahr. Genussm., 1907, *13:* 397. [b] Recalculated to degrees Ventzke from Soleil-Dubosc.

Average composition of honeys, compilation by König (138 samples). [a]

Data.	Water.	Nitrogenous matter.	Reducing sugar.			Sucrose.	Gums, etc.	Pollen and wax.	Other non-sugars.	Ash.	Phosphoric acid.
			Levulose.	Dextrose.	Total as dextrose.						
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Minimum	10.00	0.02	30.49	23.52	64.10	.....	0.12	Trace.	1.23	0.02	0.006
Maximum	33.59	2.02	48.91	42.67	79.37	12.91	.36	2.81	8.82	.68	.086
Average	**20.60**	**.76**	**38.65**	**34.48**	**72.88**	**1.76**	**.22**	**.71**	**2.82**	**.25**	**.028**
Average calculated to dry substance	.....	**0.95**	**48.65**	**43.41**	**91.75**	**2.22**	**0.28**	**0.89**	**3.60**	**0.31**	**0.35**

[a] Chem. Nahrungs- und Genussmittel, 3d ed., *1*:766.

DISCUSSION OF RESULTS.

PHYSICAL CHARACTERISTICS OF HONEYS.

The physical properties of the different honeys, color, granulation, aroma, flavor, etc., are indicated in the table only in a very general way. In color the honeys ranged from the pure white of the alfalfa, clovers, and other Leguminosæ to the very dark color of the buckwheat. As regards granulation, 80 of the 100 honeys examined were more or less crystalline; the granulation in the honeys of high purity, such as the alfalfa, was sufficient to cause solidification. In fact, this solidifying property of alfalfa and other easily granulating honeys is now utilized by packers, who supply them in the form of briquettes wrapped up in paper packages. The popular preference for a liquid honey, on the ground that it is an indication of purity, is founded upon an entirely false opinion. In many cases the granulation caused only a partial solidification of the honey, with the formation of either a thin crystalline magma or of a compact deposit of dextrose crystals, the latter frequently of some size. The granulation of honey is largely influenced by temperature, being much more pronounced in winter than in summer.

Twenty of the honeys were entirely liquid and showed no indications of granulation. This condition was especially marked in the low-purity honeys, such as those largely derived from honeydew, and in honeys of high levulose content, such as the sage and tupelo. The non-granulating property of the sage is, in fact, utilized by packers for blending in order to prepare honeys which will remain liquid.

In two cases, honeys Nos. 40 and 89, the very fluid condition of the honey was due solely to an excess of water, these honeys containing from 8 to 9 per cent more water than the general average. This large amount of water was probably due to an unripe condition of the honey as a result of insufficient evaporation or reduction of the nectar by the bees. Honeys of high water content are apt to undergo fermentation changes, and the sour taste of sample No. 40 may be ascribed to this cause.

The aroma and flavor of the different honeys were usually typical and well marked for each special class, but these could be indicated only very imperfectly in the table, owing to the difficulty of describing sense perceptions of this character. In many cases the odor of the flower from which the nectar was derived was especially pronounced, as in the pennyroyal and orange. The alfalfa, basswood, buckwheat, cotton, and several other classes of honey had also each a characteristic odor and flavor. The presence of much honeydew in a sample could usually be detected by the very marked molasses-like odor and flavor, as in honeys Nos. 72, 85, 86, 96, 97, and 98.

POLARIZATION DATA.

MULTIROTATION.

In the polarization of the various honeys listed in the table it will be noted first of all that there is a decided difference in every case between the direct polarization made immediately and that made after standing overnight. This is due to the phenomenon of multirotation or birotation, a characteristic very commonly noted in the polarization of all reducing sugars. The individual figures for birotation as given in the table represent the value determined upon the liquefied honey, the average for all the honeys listed being about 3.6. If a heavily granulated honey be dissolved without previous liquefaction, the birotation is much more pronounced. The algarroba honey, No. 35, for example, when liquefied, had a multirotation of 4.2. A sample of this same honey unliquefied gave an immediate polarization of —5.6° V. and a constant of —21.7° V. The multirotation in this case is 16.1, nearly four times that observed in the liquefied honey.

The generally accepted explanation of the phenomenon of multirotation [a] is the formation during solution of molecular aggregates of high specific rotation which gradually break down into simple molecules of lower polarizing power. In a honey which has been liquefied by warming until all crystals of dextrose are dissolved, these molecular aggregates would seem to be largely, though not entirely, broken down. The statement so frequently made that a solution of a sugar on standing will soon attain its normal constant rotation requires, therefore, some modification. No work seems to have been done upon the point of concentration at which sugar solutions begin to show multirotation, but the phenomenon probably obtains for all conditions of supersaturation. Any liquid honey which displays multirotation would probably granulate to a greater or less degree under favorable conditions. The reason that concentrated molasses, sirups, and glucoses do not exhibit multirotation would, therefore, be that the reducing sugars in these products do not exist in a condition of supersaturation.

Frühling [b] in a report upon the birotation of several honeys which he examined states that the change in rotation was the strongest in honeys which contained the largest amount of crystallized dextrose. In such granulated honeys the levorotation increases after solution in consequence of the decrease in the positive rotation of the dextrose. With honeys, on the other hand, which contain no crystals of dextrose the author above cited states that the levorotation decreases

[a] Landolt, Das optische Drehungsvermögen, 2d ed., p. 243.
[b] Zts. öffentl. Chem., 1898, 4: 410–412.

owing to the disappearance of the birotation of the levulose. This latter statement, however, requires considerable qualification, since such a decrease in levorotation as that referred to was not observed in any of the liquid honeys examined. In the case of the twenty honeys of this list which showed no indications of granulation every sample showed a decided increase in polarization toward the left.

A neglect of the phenomenon of multirotation naturally introduces a serious error in the case of those analytical constants which are derived from polarization; such, for example, as the direct polarization and the sucrose by the Clerget method. Honeys Nos. 63 and 92, for example, showed an initial rotation of +3.7 and +0.8, which would exclude them as honeys according to our standards of purity. The constant reading of these same honeys, however, was —0.3 and —10.8, which brings them within the standards as being levorotatory. In the same way honey No. 92, using the immediate polarization (+0.8), indicates by the Clerget formula 11.77 per cent of sucrose, an amount considerably above that allowed by the standards (8 per cent), whereas using the constant rotation (—10.8) a sucrose value of only 2.98 per cent is obtained.

DIRECT AND INVERT POLARIZATIONS AT 20° C.

In comparing the direct and invert polarizations of the various honeys there are several points which should be noted. The statement is sometimes made that a pure honey will rarely polarize more than —20° V. at 20° C., and that a higher reading than this, while not conclusive evidence of adulteration, may well be looked on with suspicion. This statement is hardly borne out by the analytical results given in the table, where sixteen of the 100 honeys examined polarized more than —20°, the results going as high —24.6° in a tupelo honey and —24.8° in a mangrove. A high levorotation in a honey may be due to several causes, such as imperfect sampling through sedimentation of dextrose, or to a natural preponderance of levulose in the floral nectar (the explanation in the case of the mangrove and tupelo honeys) or to the honeys being comparatively free from sucrose and dextrins of high positive rotation (the explanation in the case of the mesquit and algarroba honeys).

The invert polarizations at 20° C., owing to the removal of the disturbing influence of variable amounts of sucrose, show usually a closer uniformity than the direct polarization. The alfalfa honeys, for example, show a range of —9.4° to —20.5° V. for the direct readings, and a range of only —21.01° to —24.53° for the invert. The invert polarization is usually a good index of the purity of a honey as regards the amount of non-sugars; the alfalfa honeys, for example, having an invert polarization of —22.99° and 2.05 per cent organic non-sugars, the basswoods —12.25° and 6.52 per cent, the white oak

+5.17° and 15.47 per cent. There are, however, important exceptions to this rule, as in the tupelo honeys which had an invert polarization of —28.38° at 20° C. and yet contained 7.34 per cent of non-sugars.

CALCULATION OF SUCROSE BY CLERGET'S FORMULA.

The error resulting from a neglect of the phenomenon of birotation in the calculation of sucrose in honeys by Clerget's formula has already been mentioned. Another very serious error is that due to the change in the specific rotation of the levulose of the honey after the inversion with hydrochloric acid. This error in sugar analysis has been so thoroughly discussed by Lippmann [a] and others that no detailed study of it need be undertaken here. Tolman,[b] who has recently made an investigation of this error, shows by analyses that many honeys which when analyzed by the Clerget method appear to contain cane sugar contain in reality none at all, the error in many cases exceeding 1 per cent. From the general averages of the direct and invert polarizations given in the table (page 38) the average sucrose content of the 92 levorotatory honeys by Clerget's formula is 3.31 per cent, and the average percentage of sucrose as determined gravimetrically was 1.90 per cent, an average error of +1.41 by the Clerget formula. For the seven dextrorotatory honeys the average per cent of sucrose by Clerget's formula was 2.96 per cent and by the gravimetric method 3.01 per cent, an average error of —0.05 per cent. In the latter class of honeys, however, there was present a considerable amount of optically active non-sugars (dextrins, etc.), and the influence of the hydrochloric acid upon the rotation of these bodies may have acted as a compensating error.

On account of the numerous errors just cited in connection with the use of the Clerget method and the difficulty of introducing any correction for these errors, the determination of sucrose in honey, when accuracy is required, should be made only by the gravimetric method. A neglect of this precaution might cause injustice to the producers. Honey No. 23, for example, had been found to contain 8.95 per cent of sucrose by the Clerget method, a larger amount than that allowed by the standard (8 per cent). The gravimetric method, however, gave only 7.09 per cent, which is well within the limits allowed.

DIRECT AND INVERT POLARIZATIONS AT 87° C.

These determinations, which have been recommended for honey analysis, are based upon the fact [c] that a solution of pure invert

[a] Chemie der Zuckerarten, 3d ed., *1*: 922.

[b] U. S. Dept. Agr., Bureau of Chemistry, Bul. 73, p. 69.

[c] Lippmann, Chemie der Zuckerarten, *1*: 919.

sugar at 87° C. becomes optically inactive. Hence any positive rotation observed at this temperature is due to the presence of other optically active bodies than invert sugar. The readings at 87° were made both before and after inversion, and the difference between these readings gives approximately the percentage sucrose as found gravimetrically. The invert readings at 87° were made in acid solutions, and the changes due to specific rotation of levulose probably explain the discrepancies. It is also most probable that a slight destruction of levulose took place at 87° in the acid solution. To determine the extent of this error two 26-gram samples of sucrose were inverted and polarized at 20° and 87°, the one in acid solution and the other after neutralizing, with the following results:

Polarization of acid and neutral solutions of invert sugar at different temperatures.

Solutions.	Amount of sucrose inverted.	Temperatures.	
		20° C.	87° C.
		° V.	° V.
Acid	26 grams to 100 cc (200 mm tube)	−32.50	+1.0
Neutral	do	−31.75	.0

The acid solution polarized higher to the left at 20° owing to the increase in rotation of levulose and higher to the right at 87° on account of a slight destruction of levulose by the acid at this high temperature. It is therefore always a safer plan to neutralize the acid after inverting, before making the polariscopic readings.

It will be noted on comparing the polarization constants of the different honeys that while the invert readings at either 20° or 87° are subject to the widest variations, the difference between the polarizations at these two temperatures is a fairly constant quantity for nearly all the honeys. The range of this constant, which will be found of great value in honey analysis, is worth noting.

Range of difference in invert polarization of honeys between 20° and 87° C.

Number of samples.	Degrees Ventzke.
1	20–21
3	21–22
6	23–24
4	24–25
16	25–26
20	26–27
28	27–28
14	28–29
4	29–30
1	31–32
1	32–33
1	33–34

In other words, 50 per cent of the honeys examined gave a constant ranging from 26 to 28; 80 per cent from 25 to 29, and nearly 95 per cent from 23 to 30. It is thus seen that we have a constant for honey which will be as valuable in analytical work as the Reichert-Meissl number is in the examination of edible fats. In a number of cases, as in honeys Nos. 40 and 89, the low polarization constant is due to an excess of water in the sample. It is therefore more accurate in doubtful cases to reduce the polarization difference to a uniform moisture content or to a constant basis of reducing sugars after inversion (see p. 60).

OPTICAL INACTIVITY.

An interesting fact in connection with the polarization of honeys is that nearly every honey under certain conditions is optically inactive. This may be produced by change of temperature, and, in fact, from the data given in the table, the temperature of optical inactivity for all the different honeys may be calculated. This inactivity to polarized light may also result in some cases from birotation. For example, honeys Nos. 63 and 92 directly after solution polarized to the right; in a short time the rotation had fallen exactly to zero, after which it became negative. Such honeys as these therefore have two points of inactivity—under birotation this point is only momentary, while under temperature influence it will continue constant as long as the temperature remains constant.

ANALYTICAL DATA.

MOISTURE.

The average moisture content of the honeys in the table was 17.59 per cent, with a range of from 12.42 to 26.88. Only two of the honeys, Nos. 40 and 89, which were unripe, exceeded 25 per cent of water, the limit allowed by the Committee on Food Standards and by the German "Vereinbarungen." The average water content of 138 pure honeys listed by König was 20.60 per cent, and of 17 honeys analyzed by Lehmann and Stadlinger, 19.30 per cent, results somewhat in excess of those of American honeys.

Shutt[a] shows by numerous analyses that honey from uncapped or only partially capped combs is usually immature, containing a higher moisture content and having decidedly poorer keeping qualities than honey from fully capped combs. A practice among some bee keepers at the present day is to allow such unripe honey after

[a] Ripe and Unripe Honey. Experimental Farms Reports, 1902, p. 163. Ottawa, Canada.

straining to become reduced by evaporation [a] in the sun or by low artificial heat to the consistency of ripe honey before bottling and marketing.

INVERT SUGAR.

The average percentage of invert sugar for the honeys examined was 74.44, with a range of from 62.23 to 83.36. König's average of 168 honeys was 73.13 per cent, and Lehmann and Stadlinger's average of 17 honeys, 73.45 per cent, results somewhat lower than the American honeys, as would be expected from the difference in water content.

LEVULOSE AND DEXTROSE.

The percentages of levulose and dextrose were not calculated for the individual honeys (except in a few particular cases) but only for the general averages. A considerable variation will be noted in the proportion of these two sugars, although the levulose both in floral and in honeydew honeys is always found in excess. Two exceptions to the latter rule are noted in the cases of the cotton honey No. 58 and the wild pennyroyal honey No. 55. In the case of the cotton honey, leakage of the liquid portion of the sample from the jar explains the deficiency in levulose; an irregularity in sampling may possibly explain the excessive abnormality of the pennyroyal honey. The non-crystallizable tupelo honeys were characterized by an abnormally high percentage of levulose, over 6 per cent greater than that observed for any other honey. The general average for ninety-two levorotatory honeys was 40.50 per cent of levulose and 34.02 per cent of dextrose. The average results of 83 honeys analyzed by Soxhlet and Sieben [b] by the latter's method of destroying the levulose with sixth-normal hydrochloric acid and determining the residual dextrose, gave 38.65 per cent levulose and 34.48 per cent dextrose.

SUCROSE.

The average sucrose content of the honeys in the tables was 1.90 per cent, the samples varying from 0.00 to 10.01 per cent. Only two of the honeys exceeded 8 per cent sucrose, the limit fixed by the Standards Committee. The German "Vereinbarungen" allow 10 per cent of sucrose as the maximum for pure honey, and this figure is perhaps more liberal than that of the United States standards. The average sucrose content of the 138 honeys listed by König is 1.76 per cent with a range of 0.00 per cent to 12.91 per cent. In certain cases where bees have had access to molasses or sugar the

[a] Ripening Honey by Artificial Means. E. R. Root, A. B. C. of Bee Culture, 1903, p. 124.

[b] Zts. Ver. d. Rübenzucker-Ind., 1884, p. 837.

sucrose content of a honey may considerably exceed 10 per cent. Lippmann [a] gives the analysis of a honey gathered by bees near a sugar factory which had a sucrose content of 16.38 per cent. Cuban honeys have frequently been found to exceed 10 per cent of sucrose, a circumstance due perhaps to the bees having gained access to the products of sugar houses.

ASH.

The average percentage of ash in the ninety-two samples of levorotatory honeys was 0.18 per cent, the range extending from 0.03 to 0.90. With the dextrorotatory or honeydew honeys the range extended from 0.29 to 1.29 per cent, with an average of 0.81. The limit for ash allowed by the Standards Committee is 0.25. The German "Vereinbarungen" set no fixed limit upon ash, but state that the latter varies from 0.1 per cent to 0.8 per cent; pure honeys vary usually only from 0.10 to 0.35 per cent. Twenty of the levorotatory honeys in the table exceeded 0.25 per cent, and nine exceeded 0.35 per cent. It is evident that the limits fixed for ash under the United States standards do not include a number of samples of otherwise pure honeys. Honeys from certain sections may contain much more ash than those from others. Algarroba honey, for example, in the Hawaiian Islands contains 0.34 per cent ash, while in Arizona and Texas the mesquit honey [b] contains less than 0.15 per cent. All honeys from the Hawaiian Islands, in fact, even of the purest floral type, are distinguished by a high ash content, the average of the seven levorotatory Hawaiian honeys in the table being 0.44 per cent. Honeys containing much honeydew are also characterized by a high percentage of ash.

DEXTRIN.

In the matter of dextrin content the honeys showed considerable variation, ranging from 0.04 to 7.58 per cent for the levorotatory honeys and from 6.02 to 12.95 per cent for the dextrorotatory. König gives as the average of 173 levorotatory honeys 2.89 per cent dextrin, which is about 1 per cent higher than the average of this class of honeys in the table. Comparisons of the dextrin content of honeys analyzed by different chemists have but little value, however, on account of differences in the methods used for estimating this constituent.

The dextrins which are found in honey are apparently not derived to any appreciable extent from floral nectar, but are more probably gathered by bees from other sources, such as the gummy exudations

[a] Zts. angew. Chem., 1: 633; Chem. der Zuckerarten, 3d ed., p. 1048.
[b] See note p. 74.

of young buds or the wounded surfaces of shrubs and trees. The juice which exudes from the wounded parts very frequently undergoes a viscous fermentation, with the formation of considerable dextran, a gummy product very closely related to dextrin and possessing a high optical activity.

The juice of leaves may be still further modified through the agency of the plant-louse or aphis, the gummy secretions (honeydew) which these and other leaf-feeding insects exude having already been mentioned (p. 12). This is, in fact, the chief source of the abnormalities in the composition of honey. Sporadic outbreaks of abnormal honey in apiaries, especially in dry summers, are, in fact, not infrequent. Honey from trees such as the basswood, oak, poplar, and hickory seems especially liable to contamination with honeydew. Probably all honey contains a certain amount of this and other extraneous exudations, from the merest traces up, and the normal quantities as shown in the table merge so gradually into the abnormal that it is difficult to establish a fixed and definite line between the two classes of products. It is the usual practice to put all dextrorotatory honeys in a class by themselves, and in the present work this precedent has been followed, all honeys polarizing to the right having been included in the abnormal or honeydew class. It must be said, however, that while the point of optical inactivity offers a most convenient line of demarcation to the chemist, such a division is purely arbitrary in character and has no strict scientific basis.

UNDETERMINED MATTER.

The undetermined matter of the honeys reported in the table, taken by difference, represents (in addition to pollen grains, wax particles, and other insoluble matter) the albuminoids, fixed and volatile acids, coloring matter, aromatic bodies (terpenes, etc.), higher alcohols (mannitol, etc.), and various other bodies of indefinite or unknown character. The percentage of such undetermined matter was considerable in certain of the honeys, such as the apple blossom and several of the clovers, and a closer examination of these honeys would have been undertaken had larger amounts of the samples been available.

NITROGEN.

The percentage of nitrogen[a] was determined in a number of the honeys, with the following results:

[a] Determinations made by T. C. Trescot.

Nitrogen and protein content of various honeys.

Number of sample.	Kind of honey.	Nitrogen.	Protein.
		Per cent.	*Per cent.*
.....	Alfalfa	0.017	0.106
35	Algarroba	.035	.219
63	Basswood	.044	.275
86	White oak	.047	.294
84	Whitewood	.071	.444
85	Hickory	.076	.475
72	Poplar	.090	.563

The above results for protein are all below the average percentage of nitrogenous matter in the honeys listed by König, which was 1.08 per cent, the results ranging from 0.30 per cent to 2.42 per cent. As a general rule, honeydew honeys have a higher nitrogen content than those of a purer type.

ACIDITY.

The acid of the honey expressed as formic varied from 0.04 per cent to 0.25 per cent, with an average of 0.09 per cent; the acidity of the honeys listed by König ranged from 0.03 per cent to 0.21 per cent, with an average of 0.11 per cent. The high acidity of several of the honeys, as No. 40, was due to a slight souring of the sample through fermentation.

PENTOSANS.

One sample of pure algarroba honey and five samples containing more or less honeydew were distilled with hydrochloric acid and the furfural in the distillate precipitated with phloroglucin. The furfural-phloroglucid was filtered, dried, and weighed, and the corresponding percentage of pentosans determined according to the method of Kröber and Tollens.[a] The following values were obtained:

Determination of pentosans in different samples of honey.

Number of sample.	Kind of honey.	Pentosans.
		Per cent.
35	Algarroba	0.98
96	Hawaiian	1.00
63	Basswood	.83
85	Hickory	1.01
72	Poplar	.99
86	White oak	.96

The honeydew honeys, notwithstanding their high percentage of non-sugars, show no difference in pentosans as compared with the algarroba honey. Inasmuch as pure sucrose will give sufficient fur-

[a] U. S. Dept. Agr., Bureau of Chemistry, Bul. 107, p. 54.

fural on distillation with hydrochloric acid to correspond to 1.15 per cent of pentosans,[a] the conclusion may be drawn that pentosans are not present in honey unless in very minute traces.

TANNIN BODIES.

All of the honeys were examined for tannin by testing a solution of the honey with ferric-chlorid solution; twenty-five of the samples gave a positive reaction with this reagent; six, very marked; thirteen, distinct; and six, faint. As a general rule the honeys giving pronounced tannin reactions were high in acid, as Nos. 71, 78, and 51. In flavor, the high tannin honeys were usually characterized by a marked astringency.

COMPARISON OF HONEYS BY VARIETIES AND GROUPS.

A comparison of the honeys by varieties shows usually a well-defined agreement in composition between the individual honeys of each particular class. The alfalfa honeys, for example, are usually marked by a lower content in dextrin and undetermined matter, and a higher sucrose content than any of the other varieties. In fact, two of the eight alfalfa honeys analyzed exceeded 8 per cent of sucrose, the limit set by the Standards Committee. The relatively high purity (low content in dextrins and undetermined matter) of the alfalfa honeys was shared, but to a less degree, by other members of the Leguminosæ.

The honeys of the Compositæ were about the average as regards organic non-sugars. The Rosaceæ were low in dextrin, but all high in undetermined matter. The buckwheats seemed characterized by an almost entire absence of sucrose and by the presence of tannin bodies. The basswood honeys were all relatively high in dextrin. This was also true of the sumacs, the poplar, oak, hickory, and other tree honeys, all these containing considerable quantities of honeydew. In addition to a high dextrin content, the latter were also characterized by a relatively high amount of ash. Honey gathered from plants or blossoms containing tannin, as the sumac and hop, usually gave pronounced reactions for tannin. The tupelo, mangrove, and sage honeys were all distinguished by their high content of levulose.

Individual differences and peculiarities such as those noted can only be referred to in a very general way: the number of samples analyzed was so small for many of the varieties, and the admixture of other kinds of nectar in certain instances so uncertain that it was impossible to draw any sweeping conclusions as to the composition of each particular honey type.

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[a] Tollens, Kröber, and Rimbach; Zts. angew. Chemie, 1902, p. 508.

INFLUENCE OF ENVIRONMENT UPON COMPOSITION.

EFFECT OF HUMIDITY.

Environment or locality has frequently a very marked influence upon the composition and properties of honey. The data contained in the table, however, are not sufficient to warrant any definite conclusions being drawn upon this subject, except as regards two or three constituents. To determine with certainty the influence of environment upon the composition of the solid constituents of honey comparisons of analyses, as a rule, should be made only upon the product derived from a single variety of flowers in order to eliminate the differences which might be due to composition of the floral nectars.

In the matter of water content, however, variations in the composition of nectars would play a very insignificant part. The percentage of moisture in a honey is determined largely by the degree of ripeness or concentration to which the bees have reduced the nectar in the hive, and the work of the bees in this respect would be promoted or retarded by local atmospheric conditions of dryness or humidity. Honeys from those sections of the country which are marked by low average humidity and precipitation would, therefore, naturally have a lower percentage of water than honeys from sections of higher humidity and rainfall. A comparison of the results in the following table shows, as a matter of fact, a very decided relationship of this kind, the average humidity of the atmosphere, the average annual rainfall, and the water content of honeys from the very arid States of the Southwest and from the more humid States of the upper Mississippi being given:

Comparative table showing the relation between humidity of locality and moisture in honey.

DRY SECTION.

State.	Average humidity.[a]	Rainfall.[a]	Number of honeys.	Moisture in honey.
	Per cent.	*Inches.*		*Per cent.*
Arizona	43	9.02	3	15.25
Nevada	58	9.98	4	14.61
Utah	50	13.07	1	15.91
Colorado	54	10.34	1	15.75
Average	51	10.60	.....	15.60

HUMID SECTION.

Minnesota	78	28.80	5	19.22
Wisconsin	77	28.63	7	18.59
Illinois	75	28.39	2	18.45
Missouri	75	41.02	2	19.57
Iowa	75	27.61	1	18.69
Average	76	30.89	.....	18.88

[a] The annual average of stations in the several States from the report of the United States Weather Bureau, 1904–5.

These data are also graphically indicated on the map (page 15). It is seen that the States of the upper Mississippi, with an increase of 25 per cent in atmospheric humidity and of 20 inches in annual rainfall, produce honeys which contain about 3.5 per cent more water than the States of the arid Southwest.

HAWAIIAN HONEYS.

FLORAL AND HONEYDEW HONEYS.

The Hawaiian honeys afford a most striking example of the effect of local conditions upon composition. Reference has already been made to the higher ash content of these honeys. This circumstance in the case of the pure floral honeys is due largely to an excess of chlorids and is probably the result of the large amount of salt contained in the soil water of these islands. All Hawaiian honeys when dissolved give a strong reaction for chlorids with silver nitrate, and this peculiarity may be taken as a distinguishing characteristic of the Hawaiian as compared with most of the continental honeys.

With the lower grade Hawaiian honeys the high ash content is due to the presence of variable amounts of honeydew, which is gathered by the bees from the exudations of the leaf-hopper and leaf-aphis upon the leaves of the sugar cane. The presence of this honeydew introduces at times such abnormalities into the composition of Hawaiian honeys that the latter are very frequently condemned as adulterated, both in domestic and foreign markets. The following extract from a letter by D. L. Van Dine, entomologist of the Hawaiian Experiment Station, to the Bureau of Entomology will explain the bearing of local conditions upon the honey productions of Hawaii more fully:

Hawaii produced last year some 600 tons of honey, of which not more than 200 tons could be classed as a floral honey. The remaining 400 tons was either a distinctly honeydew honey or a blend of the honeydew honey and floral honey with decided honeydew characteristics. The source of the floral honey is, in the main, the flowers of the algarroba, *Prosopis juliflora*. The honeydew honey comes largely from the exudation of the sugar-cane leaf-hopper, *Perkinsiella saccharicida*, and the sugar-cane aphis, *Aphis sacchari*, although here in the Tropics the scale insects and related families are very abundant and a great amount of honeydew is to be found on various plants and weeds in almost any locality. The amount of floral honey that can be produced in Hawaii is limited. The algarroba forests are pretty well stocked with bees, and the present extension of the industry is in the vicinity of the large sugar-cane plantations and a few regions well supplied with certain weeds, such as lantana, *Heteropogon contortus*, *Verbena bonariensis*, guava, and so on. I do not believe Hawaii will ever produce more than 400 or 500 tons of floral honey unless honey-producing plants are introduced and propagated for the purpose. On the other hand, it seems that the amount of honeydew honey that can be produced is almost indefinite. * * * It seems to us here that this product must be honey, though varying from the floral product. It is a natural saccharine substance collected, modified, and stored in the comb by the honey bee, extracted from the comb, and without taking anything from it or adding anything to it, it is offered for

sale on the market for what it is worth, without any attempt to deceive the buyer as to its source or comparative value. The people here realize what the honey is in comparison to the mainland honeys derived from the nectar of flowers, and know the absurdity of placing it on the retail market in competition with honey of good flavor and color. For the purposes for which it is used, however, it is not only just as good as the honeys used in the bottling and comb-honey trade, but the bakers have found it has baking properties superior to our own floral honeys and many of those produced on the mainland. * * * The honeydew honey has a distinct market of its own to the baking and confectionery trade, and for this purpose is preferred to the algarroba honey. On the market in New York the local bee men receive from one-half of a cent to 1 cent per pound more for their honeydew honey than for the algarroba honey, for the reason that the honeydew honey has better baking and boiling properties. Our white honey loses many of its honey characteristics after it goes into the oven, and the honeydew honey does not. * * *

Aside from the typical honeydew honey and the white honey there is produced here a large amount of honey which is, in the main, a blend of the two types. This blend is brought about by the bees themselves, and much of this honey, though possessing the honeydew flavor and the dark color, is within the standard, except for the ash content. Then, also, there is a small amount of honey of dark color with a very pleasant, delicate flavor that compares very favorably in its analyses with the white honey. This latter honey is from the flowers of various weeds and a blend of the honeys produced from the flowers of weeds, algarroba, rice, etc. * * *

It will be seen from the above that the local conditions affecting the composition of honeys in the Hawaiian Islands are exceedingly complex.

The composition of the Hawaiian honeydew is given in the table under sample No. 96. The product contained considerable pure honey, as was shown by the presence of various kinds of pollen. The abnormalities of the sample as regards polarization, ash, and dextrin are too evident to call for comment. The sucrose and acidity are considerably higher than the average for Hawaiian floral honeys. In many of its characteristics the product agrees with the sample of leaf-louse or aphis honey analyzed by Wiley:[a]

Polarization at 30° C	+23.10°
Polarization at 88° C	+40.30°
Sucrose (per cent)	5.21
	Per cent of dry substance.
Invert sugar	71.58
Sucrose	6.04
Ash	.62
Dextrin, etc. $[(\alpha)_D = +105]$	21.76

Wiley remarks in this connection: "The three phenomena, right-handed polarization at ordinary temperature, great deficiency in invert sugar, and high ash content, are analytical points by means of which a plant-louse honey can be differentiated from a pure floral honey."

[a] J. Amer. Chem. Soc., *14* : 350.

DEXTRINS OF HAWAIIAN HONEYDEW.

Attempts were made to separate the dextrins of the honeydew, both by fractionation with alcohol and by fermentation. The results obtained by fractionating a concentrated solution of the honeydew with successive portions of absolute alcohol are given in the following tables. Forty grams of the honeydew were dissolved to 40 cc with water and then made up to 500 cc with absolute alcohol, shaking continuously. After twenty-four hours standing all dextrinous matter had settled out and the clear alcoholic solution (fraction 1) decanted, evaporated, and the specific rotation of the solid matter determined from the polariscope reading and the specific gravity. The precipitated dextrin was redissolved in a minimum quantity of water and reprecipitated. The clear solution (fraction 2) was evaporated and polarized as before. The residue was redissolved and reprecipitated twice more (fractions 3 and 4), the final precipitate constituting fraction 5.

	Specific rotation. $[\alpha]_D$
Solids of original sample (84.54 per cent of honeydew)	+ 14.0
Solids of fraction 1 (about 25 per cent of honeydew)	— 6.9
Solids of fraction 2 (about 40 per cent of honeydew)	+ 15.1
Solids of fraction 3 (about 10 per cent of honeydew)	+ 54.3
Solids of fraction 4 (about 2.5 per cent of honeydew)	+115.6
Solids of fraction 5 (about 3 per cent of honeydew)	+117.0

Fractions 4 and 5 consisted mostly of dextrins and resembled one another closely in properties and appearance. The various fractions might have been still further split up, as some dextrin was present in the lower polarizing fractions, and some reducing sugar in fractions 4 and 5.

A fermentation test of the diluted honey (50 grams to 300 cc), continued for five days, showed a residue of 16.42 per cent of matter not fermented. The percentage of non-fermented sugar was 3.83 per cent, leaving 12.59 per cent of unfermented solids non-sugar (dextrins, acids, ash, etc.). The residual dextrins in the fermented residue were precipitated with alcohol and gave upon polarization a specific rotation of + 115.0, a value differing but little from that of the dextrins of fractions 4 and 5 in the previous experiment.

It is interesting to note in this connection that Hilger [a] isolated from a coniferous honey one dextrin of specific rotation +119.9 while dextrins from three other lots of coniferous honey gave specific rotations of +125.59, +131.28, and +157.00. These coniferous dextrins, however, differ from those of the Hawaiian honeydew in being plant exudations and not insect secretions. All kinds of dextrins, irrespective of their origin, are probably more or less modified in

[a] Zts. Nahr. Genussm., 3: 110–126.

the honey stomach of the bee and during the course of evaporation in the hive. Raumer[a] found, for example, that of 532 grams of dextrin in glucose sirup which was fed to bees, only 249.98 grams (47 per cent) were found in the honey, showing that these dextrins had been changed into reducing sugar. Beckmann[b] also showed that the erythrodextrin of starch sirup had been so modified by the bees during feeding that the resultant compound no longer gave the characteristic reaction with iodin. The starch dextrins seemed to have been transformed into those characteristic of ordinary honey.

BLENDS OF HONEYDEW AND PURE FLORAL HONEY.

Reference has already been made to the probability that all honeys contain variable amounts of honeydew and other foreign exudations gathered by the bees. A good illustration of the effect of the natural blending produced by the bees upon the composition of honey is shown in the analyses of Hawaiian honeydew and a few of its blends as given in the table (Nos. 96, 97, 98, 99, and 100). Here a regular gradation is noted in polarization, invert sugar, ash, dextrin, and acidity, with the decrease in quantity of honeydew. There is also a falling off in the sucrose content of the honey, as the amount of honeydew diminishes; and this is to be expected from the relatively high sucrose content of the honeydew. Two of the blends given in the table (p. 37) were levorotatory and were normal in every respect except as regards a rather high ash content.

The presence of honeydew has also a very pronounced effect upon the physical qualities of the honey. The light-colored honeys are very much darkened through the blending with honeydew and the property of granulating is also much diminished. The presence of honeydew in very large amount also affects the flavor and odor of honey, giving it a taste and smell resembling that of molasses.

The influence of honeydew upon the physical properties of honey may be seen from the colored plate representing a series of blends of algarroba honey and honeydew taken from a large number of samples sent to the United States Department of Agriculture by the Hawaiian Experiment Station. The white crystalline algarroba honey stands at one end of the series and the very dark liquid honeydew at the other. All shades of honey with varying degrees of granulation come between.

From the polarizations and analyses of these samples (as given in the table, p. 56) it will be seen that there is a range in direct polarization from —22.0 to +24.5; in ash, from 0.34 per cent to 2.04 per cent; in reducing sugars, from 76.84 per cent to 59.76 per cent,

[a] Zts. anal. Chem., *41*: 239.
[b] Zts. anal. Chem., *35*: 281.

and in organic matter not sugar, from 1.41 per cent to 15.88 per cent. In sucrose also there is an irregular increase from 3.58 to 7.2 per cent, this increase becoming more regular as soon as the quantity of honeydew is sufficient to mask the variation in sucrose content of the individual honeys in the series of blends. The granulation of the blends decreases with the increase of honeydew and ceases at about the point of optical inactivity. The latter point, as has been said, is taken by the chemist as the arbitrary dividing line between normal and abnormal honeys, and bee keepers in the Hawaiian Islands who are troubled with honeydew have in the matter of granulation a rough guide for the classification of their products. If the honey granulates, it may be put in the normal class; if it remains liquid for any length of time, it probably belongs to the class of honeydews. This statement does not apply in general to mainland honeys.

The dextrorotatory honeydew honeys can not be regarded as adulterated, in the strictest sense of the word; nevertheless they are frequently so pronounced by chemists, who, in the general work of routine, are often satisfied with a most superficial examination and regard dextrorotation or high ash content as certain evidence of adulteration. The means of distinguishing between abnormal and adulterated honeys will be given under the following caption.

Polarizations and analyses of honeydew blends.

Data.	Algarroba honey.	Blends.[a]								Honeydew.[a]
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Polarization, direct (°V.)	−22.00	−18.3	−14.3	− 8.7	− 0.3	+ 0.5	+ 4.0	+ 8.9	+19.2	+24.5
Polarization, invert (°V.)	−27.61	−21.4	−17.3	−11.5	− 3.8	− 4.2	− 1.0	+ 3.2	+12.4	+15.3
Sucrose (per cent)	3.58	2.4	2.3	2.2	2.7	3.7	2.3	4.5	5.3	7.2
Reducing sugar (per cent)	76.84	76.64	77.28	72.36	65.56	66.16	67.28	63.08	58.92	59.76
Ash (per cent)	.34	.58	.69	.72	1.06	1.11	1.12	1.33	1.77	2.04
Nonsugars (per cent)	1.41	1.67	1.81	7.17	13.52	12.09	11.84	15.27	17.68	15.88

[a] Analyses by Miss A. R. Thompson; quoted by permission of the Hawaiian Agricultural Experiment Station.

ADULTERANTS OF HONEY AND THEIR DETECTION.

The three materials employed most extensively at present in the adulteration of honey are sucrose or cane sugar, commercial glucose or starch sirup, and invert sugar. Other forms of adulteration, such as the addition of water, starch, etc., are but little practiced, owing to the suspicious changes which these adulterants produce in the physical appearance of the honey.

BLENDS OF ALGARROBA HONEY AND HONEYDEW FROM THE HAWAIIAN AGRICULTURAL EXPERIMENT STATION.

H. LIEBEN & CO. BALTIMORE

CANE SUGAR.

Cane sugar may be introduced into honey in two ways, either by direct addition, or by feeding it to the bees.[a] The addition of sucrose in amounts that would not cause the honey to exceed the standard does not, of course, admit of detection, and this practice, it is said, is followed by certain manufacturers who bottle honey upon a large scale.

Cane sugar which has been introduced into honey by feeding it to bees is much more difficult to detect, owing to the fact that the bees invert the greater part of the sucrose. Raumer[b] found that of 456 grams of sucrose fed to bees only 16.97 grams (3.7 per cent) were found in the product stored by the bees. Hefelmann,[c] however, found that bees could invert only about two-thirds of the cane sugar fed, the resulting compound containing 30 per cent of sucrose. In an experiment conducted by the Bureaus of Chemistry and Entomology in which sugar sirup alone was fed, a mixture was obtained having the following composition:

Direct polarization	°V.	+ 4.0
Indirect polarization	°V.	−17.6
Sucrose $= \frac{(a-b)\ 100}{144 - \frac{t}{2}}$	per cent.	16.4
Solids by vacuum	per cent.	80.75
Ash	per cent.	.03
Reducing sugar	per cent.	58.35
Calcium		None.
Sulphate		Trace.
Acid in 1 gram honey as formic	per cent.	.090
Nitrogen	per cent.	.027
Acid to neutralize ash in 1 gram honey $\left(\text{cc}\ \frac{N}{10}\ \text{acid}\right)$		.070

This product was colorless and entirely devoid of the flavor and aroma characteristic of honey. About 80 per cent of the total sugar fed seems to have undergone inversion, a value corresponding closely to the results previously quoted from Bonnier (p. 12), showing the ratio between the sucrose and sainfoin nectar and sainfoin honey. The majority of experiments show that sugar-fed honey is characterized by a content of sucrose considerably above that allowed by the standards. In case, however, such honeys are reduced by mixing with pure floral honey there is no possible means by which the prac-

[a] It is the consensus of opinion among leading bee keepers that the feeding of cane sugar to bees for honey production is not profitable.

[b] Zts. anal. Chem., *41*: 339.

[c] Centrbl., 1894, *65* (*2*): 585.

tice of sugar feeding can be detected. Since the practice of sugar feeding is not profitable commercially these facts have only a theoretical interest.

COMMERCIAL GLUCOSE.

The addition of commercial glucose has been the most common form of honey adulteration practiced in the past. Starch sirup resembles the best liquefied honey in color and consistency, so that the appearance of a sample does not indicate such adulteration. Glucose is used very largely to improve the appearance of low-grade, very dark-colored honeys, and also to modify the taste of the more rank and strongly flavored natural honeys. It is also used for the purpose of preventing granulation, the addition of only a small amount of glucose checking the crystallization of the honey permanently. The adulteration with glucose is made after straining or extracting. Attempts to introduce glucose sirup into honey by feeding have not proved successful, as the bees refuse to take this sirup as food. If attempts are made to coerce the bees by preventing their access to other supplies of food, they will take the glucose but will soon sicken and die, probably through inability to stand a protracted diet of the starch dextrins.

QUALITATIVE TESTS.

The method [a] sometimes practiced of detecting glucose in honey by precipitation of the dextrin with strong alcohol is not reliable, as the natural dextrins of honey are also precipitated. One of the quickest and simplest methods of detecting commercial glucose in honey is the test for erythro- or amylo-dextrin with iodin proposed by Beckmann: [b]

A solution of the suspected honey in water (1:1) is prepared and treated with a few cubic centimeters of iodin solution. If glucose be present the solution turns red or violet, the depth and character of the color depending upon the quantity and nature of the glucose employed for adulteration. A blank test with a pure honey, using the same quantity of iodin solution, should be made at the same time for the purpose of securing an accurate comparison of color.

Beckmann [c] has made this test even more sensitive, when only very small amounts of glucose are present, by first precipitating the dextrins of the honey with alcohol and applying the iodin test to a solution of this precipitate in a small amount of water.

All of the 100 pure honeys analyzed were tested with iodin solution, but none was found to give the reaction. The test is

[a] Allen, Commercial Organic Analysis, 1905, *1*: 382.
[b] Zts. anal. Chem., 1896, *35*: 267.
[c] Loc. cit.

one of great value, since the chemist is enabled to detect small amounts of glucose which it would be impossible to recognize with the polariscope. It should be noted, however, in passing, that there are some glucose sirups of high conversion and certain maltose sirups which do not give any reaction with iodin.

QUANTITATIVE DETERMINATIONS.

The chemical literature upon honey analysis contains many descriptions of methods for estimating glucose. A discussion or review of these would be impracticable and attention will be called only to a few of the methods in most general use. The European methods and formulas are based upon polarization constants obtained from foreign glucoses and are not generally applicable to the American class of products.[a]

The provisional method of the Association of Official Agricultural Chemists for estimating glucose in honey[b] consists in polarizing the inverted solution at 87° C.; this reading multiplied by 100 and divided by 163, the average polarization Ventzke of a normal weight of commercial glucose, gives the approximate percentage of commercial glucose. This method of calculation is based upon the fact that solutions of pure invert sugar are optically inactive at 87°, and any dextrorotation at this temperature is due to added glucose. The results of the table show, however, that all honeys are dextrorotatory to a greater or less extent at 87°, so that the values obtained by this method of calculation must be used with extreme caution.

Another method of calculation, used very generally in European countries, is based upon the variation in the invert polarization of the sample from the average polarization of pure honey. The following formula is deduced from the average invert polarization of the honeys in the table (−17.5) and from the average polarization of glucose (+175):

x=per cent of honey in sample,
y=per cent of commercial glucose in sample,
P=invert polarization Ventzke of normal weight of sample.

$$x+y=100,$$
$$-0.175\,x+1.75y=P.$$
$$y=\frac{P+17.5}{1.93}$$

This method of calculation has been found to give somewhat closer results than that of the Association of Official Agricultural Chemists. It is open, however, to the objection that no allowance

[a] Analyses of American and European glucose sirups by Herzfeld, Zts. Ver. d. Zucker-Ind., 1907, 2: 614.

[b] U. S. Dept. Agr., Bureau of Chemistry, Bul. No. 107, p. 70.

is made for the wide range in the invert polarization of individual honeys (—29.26 to +14.96 in the table), so that a considerable error may be introduced into the final result. Another objection, which also holds true for the method of the official chemists, is that no account is taken of the possible variation in polarization of the glucose used for adulteration. The value +175 holds only for a certain class of products; with glucose sirups of high conversion the polarization may sink below +150, and with honeys adulterated with materials of this description the methods just described would give too low results.

A third possible method of estimating the glucose in honey is based upon the lowering of the difference in invert polarization between 20° and 87°. For the honeys in the table the average value for this constant was found to be 26.71. Since this difference in polarization of pure honey is due entirely to the percentage of levulose, the addition of any non-levulose-containing material whose polarizing power is not affected by change of temperature will cause a depression in the polarization difference between 20° and 87° proportional to the amount of adulterant used and irrespective of its specific rotation. The polarization difference of pure honeys, however, may be considerably influenced by variations in moisture content or through an excess of honey dextrins and other nonsugars. It is therefore better to reduce the polarization difference to the constant basis of reducing sugars after inversion before making the calculation for added glucose. The method of doing this is as follows:

The difference in invert polarization between 20° and 87° is multiplied by 77, the average percentage of invert sugar after inversion for pure honey, and this product is divided by the percentage of invert sugar after inversion found in the sample. This quotient is the corrected polarization difference which, multiplied by 100 and divided by 26.7, will give the percentage of pure honey in the sample. One hundred minus the per cent of pure honey equals the per cent of glucose.

In the following table the polarizations of five honeys of considerable range in composition, selected from the list of 100 analyses, and of mixtures of the same with 20 per cent of commercial glucose, are given, together with the percentage of glucose as calculated by the three methods described.

Polarization of honeys and glucose mixtures, with calculated percentages of glucose by different formulas.

Number.	Kind of sample.	Direct polarization, 20° C.	Invert polarization.		Polarization difference (87°−20°).	Invert sugar after inversion.	Polarization difference corrected to 77 per cent invert sugar.	Calculated glucose.		
			20° C.	87° C.				Invert polarization at 87° C. ÷1.63.	(Invert polarization at 20° C. −17.5)÷1.93.	100−(corrected polarization difference×100÷26.7).
		°V.	°V.	°V.	°V.	P. ct.	°V.	P. ct.	P. ct.	°V.
2	Alfalfa	−19.5	−22.66	+ 3.52	26.18	77.84	25.90	2.16	0.00	3.00
	Alfalfa + 20 per cent glucose	+19.4	+16.88	+35.82	18.94	70.01	20.83	21.97	17.82	21.98
60	Hop vine	−12.6	−16.83	+ 9.68	26.51	75.83	26.92	5.94	.35	.00
	Hop vine + 20 per cent glucose	+24.9	+21.54	+40.74	19.20	68.14	21.70	25.00	20.28	18.72
84	Whitewood	− 4.9	− 9.68	+15.40	25.08	71.88	26.87	9.45	4.06	.00
	Whitewood + 20 per cent glucose	+31.1	+27.26	+45.32	18.06	64.99	21.40	27.80	23.25	19.85
63	Basswood	−· .3	− 1.32	+23.21	24.53	70.60	26.75	14.24	8.40	.00
	Basswood + 20 per cent glucose	+ 3.48	+33.94	+51.57	17.63	63.97	21.22	31.64	26.72	20.52
86	White oak	+11.0	+ 5.17	+28.60	23.43	70.44	25.61	17.56	11.23	4.08
	White oak + 20 per cent glucose	+43.8	+39.14	+55.88	16.74	63.84	20.20	34.28	29.35	24.35

It will be seen from the results in the table that with admixtures of low purity honeys and glucose there is a considerable error in the calculation of the percentage of added adulterant. The results obtained by any method of glucose estimation have only an approximate value, and in no case ought such analytical results as those obtained for the pure basswood or white-oak honey to condemn a sample as being adulterated. In all suspicious or doubtful cases confirmatory tests such as that with iodin should be employed.

GRAPE SUGAR OR COMMERCIAL DEXTROSE.

There is no absolute method for the estimation of added grape sugar in honey, yet the addition of this may often be inferred with a fair degree of certainty. A dextrorotatory honey which gives no reaction with iodin and is, at the same time, comparatively low in dextrins and other solids not sugar, contains, in all probability, added grape sugar. The "Vereinbarungen"[a] set the minimum for the non-sugars of honey at 1.5 per cent; such a standard has but little value, however, since it would not cover the case of low-grade honey and dextrose mixtures. If the difference in the invert polarization of a honey between 20° and 87° falls below 20 and the percentage of reducing sugars is normal and no reaction for amylo- or erythrodextrin is obtained with iodin, then commercial dextrose has, in all probability, been added.

[a] Part 2, 1899, p. 121.

Considerable caution is required before drawing positive conclusions as to the addition of grape sugar to a honey, since, as has already been noted, the crystalline deposits in partially granulated honey consist entirely of dextrose, and if the liquid part has been poured off, or otherwise removed, results indicating an apparent addition of grape sugar may be obtained.

DISTINCTION BETWEEN HONEYDEW AND GLUCOSE HONEYS.

Although the dextrorotatory or honeydew honeys are excluded by the standards from the class of pure honeys, they are not adulterated, in the strict sense of the word. It is important, therefore, that the chemist be able to differentiate between honeys which are dextrorotatory as the result of purely natural conditions and honeys which are dextrorotatory as the result of adulteration.

Numerous methods have been devised for this purpose. One of the first of these proposed by Haenle is based upon the supposition that honey dextrins of all kinds are easily diffusible through parchment, while dextrins derived from starch are not. This supposition has not, however, been verified by subsequent experiments. A second method recommended by Sieben [a] is based upon the difference in fermentation of the two kinds of dextrins, the dextrins of honey being readily fermented, while those of glucose are not. The observations of Sieben, however, have not been fully confirmed, except in the case of some special yeasts, such as *Saccharomyces ellipsoideus*.

Another process given by Beckmann[b] has given better satisfaction and is based upon the fact that the dextrins of starch sirup or glucose, more especially their barium derivatives, are readily precipitated by methyl alcohol, and the dextrins of floral and coniferous honey are not. The dextrins of honeydew are, however, more or less precipitated by this treatment, so that the mere formation of a precipitate is of but little value as a test with very abnormal honeys. In such cases the precipitate may be dissolved and tested with iodin for amylo- or erythro-dextrin, although, as has been previously noted, this test may fail completely with a certain class of glucose products.

A fourth process used by König and Karsch [c] depends upon the fact that, after precipitating the dextrins by absolute alcohol, the resulting solution after inversion in case of natural honeys will show a levorotation; with honeys containing 25 per cent or more of glucose,

[a] For a description of this and other methods for distinguishing between abnormal and adulterated honeys the reader is referred to König's Untersuchung landwirtschaftlich und gewerblich wichtiger Stoffe, 3d. ed., p. 593.

[b] Zts. anal. Chem., 1896, *35*: 263; Zts. Nahr. Genussm., 1901, *4*: 1065.

[c] Zts. anal. Chem., 1895, *34*: 1.

a dextrorotation. This method has been employed considerably in the sugar laboratory of the Bureau of Chemistry and has been found to be of value as a confirmatory test. The method as described by König is as follows:

Forty grams of honey are dissolved in a cylinder with water to 40 cc. Of the homogeneous solution 20 cc are transferred to a 250 cc flask and filled up to the mark with absolute alcohol with slow addition and constant shaking, and then allowed to stand two or three days, with occasional agitation. At the end of this time all the dextrin has settled out. After shaking the solution is filtered and 100 cc of the filtrate evaporated until free from alcohol. The liquid residue, with the addition of a little subacetate of lead and sodium sulphate, is made up to 20 cc with water and the filtered solution polarized. Dextrorotatory natural honeys show by this method a levorotation; honeys adulterated with dextrose or glucose to the extent of 25 per cent or more, a dextrorotation. In case the honey contains a large amount of sucrose the solution should be inverted with hydrochloric acid before polarizing.

The points upon which most reliance has been placed in this laboratory in the differentiation of abnormal and glucose honeys are, first, the difference in invert polarization between 20° and 87° (corrected to 77 per cent of invert sugar); second, the reaction of the honey and of its precipitated dextrin toward iodin (Beckmann's test); third, the polarization of the inverted solution after precipitation of the dextrin with absolute alcohol (method of König and Karsch). In addition to the above, the quantity and character of the ash, acidity, and the microscopic examination of pollen, starch, etc., are all of value in determining the origin of suspicious samples.

INVERT SUGAR.

The adulteration of honey with invert sugar is much more difficult to detect than the addition of glucose or starch sirup. Invert sugar, i. e., a mixture of the sugars levulose and dextrose in equal amounts, constitutes nearly three-quarters of honey itself, so that the detection of added invert sugar becomes a possibility only in so far as the non-sugars of the honey are modified, either in quantity or through the addition of extraneous substances produced in the manufacture of the invert sugar used for adulterating.

Before discussing methods for the detection of invert sugar in honeys a short description should be given of the methods used for the preparation of invert sugar sirup.

PREPARATION OF INVERT SUGAR SIRUP.

The methods generally employed for the preparation of invert sugar sirup consist in heating to gentle boiling concentrated cane-sugar solution with a very small amount of mineral or organic acid (hydrochloric, tartaric, or formic). The inversion is completed very

rapidly at the high temperature, and the residual acidity is so small (no greater than in pure honey) that no further treatment of the sirup is required.

By the method of Herzfeld,[a] which is used quite extensively in Germany for preparing artificial honey, 1 kilogram of refined sugar is heated with 300 cc of water and 1.1 gram of tartaric acid to boiling and maintained at this temperature until the solution acquires a golden yellow color (one-half to three-quarters of an hour). This preparation is said to improve greatly the appearance and flavor of low-grade honeys. An invert sirup prepared by Herzfeld's process had a rich golden color and a mild, pleasant flavor. On standing for a few weeks it began to granulate, the dextrose soon crystallizing to a solid mass. The composition of this product was as follows:

	° V.
Direct polarization, 20°	— 6.2
Constant polarization, 20°	— 9.5
Birotation	3.2
Invert polarization, 20°	—16.94
Invert polarization, 87°	+ 4.84
Difference	21.78

	Per Cent.
Water	16.32
Invert sugar	73.38
Sucrose	4.36
Ash	0.00
Dextrin (absolute alcohol precipitate)	1.08
Undetermined	4.86
	100.00
Acidity as formic acid	0.06

This analysis, except for the deficiency in ash, agrees very closely with that recorded for pure honeys. It conforms in every respect with the limits set by the various standards. The practical impossibility of estimating the amount of such a product in honey mixtures from the polarization or chemical analysis is at once apparent. As compared with pure honey the difference in invert polarization between 20° and 87° is rather low, owing to a slight destruction of the levulose at the high temperature of inversion. In fact, this low difference is characteristic of all invert sugar sirups prepared at a high temperature.

Invert sugar may also be prepared by inverting sucrose with larger quantities of acid at a lower temperature. With such products, however, the excessive acid has to be removed and this increases considerably the cost of manufacture.

[a] Zts. Ver. d. Zucker-Ind., *31*: 1988.

POLARISCOPIC AND CHEMICAL METHODS FOR DETECTING INVERT SUGAR.

Polarization has been used to some extent by chemists in this country for detecting inverted sucrose in honey. If the polarization of a honey exceeded —20° V. at 20° C. it was supposed to indicate the addition of invert sugar. The original authority for this statement has not been found. It is hardly necessary to state that the test is altogether valueless; fifteen of the one hundred pure honeys, as has already been noted, gave a direct polarization exceeding —20° V. The non-validity of this test is also further shown by the fact that invert sugar sirups may polarize considerably below —20° V., as in the analysis of the Herzfeld sirup. While an 80 per cent solution of pure invert sugar (26 grams to 100 cc, normal weight) should polarize at about —26° V. at 20° C., the invert sirups as made by the Herzfeld and by similar processes usually polarize considerably below —20° V., owing to the destruction of some of the levulose, as previously stated.

Another test is proposed by König,[a] which is based upon the lowering of the percentage of non-sugars by the addition of invert sugar. He says: "If the honey contains less than 1.5 per cent of soluble non-sugars (calculated from the difference between soluble solids and total sugar), it is to be regarded as an indication of the addition of artificial invert sugar, cane sugar, or grape sugar."

This test, however, has but very little value. Seven of the pure honeys in the table contained less than 1.5 per cent of soluble non-sugars, this being very frequently the case with honeys of low dextrin content, as the alfalfa. Then, again, the invert-sugar preparation itself may contain considerably more than 1.5 per cent of non-sugars, as in the Herzfeld sample, which contained 5.94 per cent of dextrin and undetermined matter. A third objection is that even with the purest preparation of invert sugar it would be impossible to detect adulteration if very low grade honeys of the honeydew type were used for mixing. Over 80 per cent of pure invert sugar could be mixed, for example, with the white oak honey No. 86, and the percentage of soluble non-sugars would still be maintained above 1.5 per cent.

COLORIMETRIC TESTS FOR INVERT SUGAR.

The uncertainty and practical impossibility of basing a judgment upon the polariscopic or chemical constants of a honey as to the presence of added invert sugar have led chemists to make use of colorimetric tests, the reaction depending upon the presence, either in the honey or in the invert-sugar preparations, of some compound which even in traces would give some characteristic color reaction.

[a] König's Untersuchung landwirtschaftlich und gewerblich wichtiger Stoffe, 3d ed., p. 596.

LEY'S AMMONIACAL-SILVER TEST.

One of the best known of such colorimetric tests in Germany is that of Ley,[a] which is thus described:

(*a*) *Preparation of the reagent.*—Ten grams of silver nitrate are dissolved in 100 cc of water and the solution treated with 20 cc of 15 per cent sodium hydrate solution. The precipitate of silver oxid is collected on a filter, washed with 400 cc of distilled water, and then dissolved in 10 per cent ammonia. The solution is afterwards made up with the ammonia to a weight of 115 grams. The reagent as thus prepared is preserved in a well closed bottle and, if protected from the action of light, is quite stable.

(*b*) *Execution of the test.*—A solution of the honey to be examined is made by dissolving 1 part of the same in 2 parts of water. Five cubic centimeters of the filtered solution are placed in a test tube and 5 drops of the silver reagent added. After mixing, the test tube is closed with a plug of cotton and placed in a boiling water bath. The operation should be carried out away from the direct sunlight, and the tube placed in the bath immediately after the addition of the reagent, otherwise color changes may set in which are the result of the action of light. After five minutes the test tube is removed from the bath and the color of the liquid observed.

(*c*) *Results of the test.*—Solutions of natural honeys show, after the treatment described, a dark color; the body of the liquid is not directly transparent and is more or less fluorescent in reflected light. Heather honeys especially show the latter characteristic. On shaking the tube the surface of the liquid becomes a clear brownish red and leaves a brownish-green or yellowish-green tint upon the surface of the glass. This greenish color tone is one of the characteristic features of the reaction. Honey substitutes or mixtures of the same with natural honey after similar treatment appear a dirty brown or black and do not exhibit on shaking the characteristic greenish tint above referred to.

The reaction of Ley was applied to nearly all of the 100 pure honeys in the list. It was found that, as a rule, much more dependence was to be placed upon the brownish body color of the liquid on shaking than upon the greenish after-tone; the latter, in fact, was very uncertain in many of the samples, whereas a characteristic brown varying in intensity from light red to purplish was produced in all the honeys, even those of a pronounced honeydew type. The reaction failed completely with all samples of invert sirup, whether prepared by hot inversion, as in the method of Herzfeld, or by inversion at a low temperature. The character of the color reaction with a number of pure honeys, with different invert-sugar preparations, and with mixtures of the latter with pure honey is shown in the following table:

[a] Pharm. Zts., 1902, 47: 603.

Ley's colorimetric test for invert sugar applied to pure honeys and honey substitutes.

PURE HONEYS.

No. of sample.	Kind of honey.	Reaction.	
		In cold.	After five minutes heating.
1	Alfalfa	No change	Brownish purple.
10	White clover	do	Reddish brown.
22	do	do	Clear chocolate brown.
24	Alsike clover	do	Deep purplish brown.
28	Sweet clover	do	Clear chocolate brown.
35	Algarroba	Dense white precipitate	Coffee brown.
38	Dandelion	White cloudiness	Purplish brown.
39	do	No change	Chocolate brown.
41	Golden-rod	do	Dark brown.
44	Wild aster	do	Chocolate brown.
48	Raspberry	do	Purplish brown.
51	Buckwheat	Deep wine color	Yellowish brown.
53	Wild buckwheat	No change	Clear brown.
56	Sage	do	Dirty brown.
68	Basswood	do	Purplish brown.
72	Poplar	do	Greenish brown.
73	Willow	do	Deep brown.
75	White alder	do	Reddish brown.
79	Sumac	do	Chocolate brown.
80	Mangrove	White precipitate	Do.
81	do	do	Do.
82	Tupelo	No change	Do.
83	do	do	Dark brown.
86	White oak	do	Chocolate brown.
90	Fall flowers	do	Dark brown.
96	Hawaiian honeydew	Dense white precipitate	Chocolate brown.
97	Hawaiian honeydew blend	do	Dark brown.
98	do	do	Clear brown.
99	do	do	Dark brown.

HONEY SUBSTITUTES.

.....	Herzfeld's invert sirup	No precipitate	Dark gray; no brown.
.....	Formic acid invert sirup	do	Light gray; no brown.
.....	Sulphuric acid invert sirup prepared in cold	Intense purple	Gray; no brown.
.....	Commercial glucose	No change	Do.
.....	Algarroba honey + ½ Herzfeld's invert sirup	White precipitate	Dark gray; trace of brown.
.....	Algarroba honey + ¼ Herzfeld's invert sirup	do	Dark gray; decided brown.

The reaction of Ley has been tested recently by Utz [a] who gives the color appearance with sixty-one different honeys. Utz places most dependence upon the yellowish green after-tone, but notes that this failed completely with a number of pure honeys. Ley also found among fifty-nine honeys five which failed to give the test. The test, therefore, is not an infallible one. As was previously stated, the greenish after-tone failed with so many of the American honeys that no special reliance could be placed upon this phase of the reaction. The brownish color of Ley's reaction was found to have a distinctive value, however, as a confirmatory test in honey examination, though the chemist should thoroughly familiarize himself with the test upon samples of pure and artificial honey before employing it in commercial work. For honeys which have been heated to boiling for any length of time, Ley's test was found to be valueless.

[a] Zts. angew. Chem., 1907, *20*: 993.

ANILIN-ACETATE TEST.

The use of concentrated anilin acetate solution has been found in this laboratory to be of great value in testing for invert sugar. The reaction with this reagent is dependent upon the fact that in making invert sugar, by the Herzfeld and similar processes, a small amount of furfural is produced at the high temperature of inversion, which is sufficient to impart a red or pink coloration to the anilin acetate solution when the latter is brought into contact with the honey. The method of conducting the test is as follows:

(*a*) *Preparation of reagent.*—This should be freshly prepared each time before using. Five cubic centimeters of chemically pure anilin are shaken up with 5 cc of water and sufficient glacial acetic acid added (2 cc) to just clear the emulsion.

(*b*) *Execution of test.*—Five cubic centimeters of a concentrated solution of the honey (1:1) are treated in a test tube with 1 to 2 cc of the anilin reagent. The latter is allowed to flow down the walls of the tube so as to form a layer upon the honey solution. If, when the tube is gently agitated, a red ring forms beneath the anilin solution, this color becoming gradually imparted to the whole layer, artificial invert sugar is present.

The above test was applied to all of the pure honeys listed in the table, but with negative results. It may be said, therefore, that there are no substances in natural honey which will react with anilin acetate. It was found possible to detect by this method as small an amount as 5 per cent of Herzfeld's invert sirup in a mixture with pure honey. With natural honeys which have been boiled or heated to a high temperature for any great length of time, traces of furfural are formed just as in the invert-sugar sirups, and these honeys will then react with the anilin reagent. The boiling of honeys, however, is a most questionable operation at best, the flavor of the honey being completely destroyed by this process of cooking. Careful producers and bottlers of honey take extreme pains in putting up their products not to expose the extracted honey to a temperature exceeding 80° C. (176° F.). A positive reaction of a honey with anilin acetate may, therefore, be regarded as an almost certain indication of adulteration with invert sugar. The two tests with the Ley reagent and with the anilin acetate give good confirmatory reactions, the experience in the Bureau of Chemistry having shown that honeys responding to the one test would almost invariably give a positive reaction with the other.

CONCLUSIONS.

The results of the foregoing work upon the composition of American honeys and the methods of detecting adulteration have been applied to the analysis of a large number of commercial honeys. The results of these examinations can not be published as yet, owing to certain requirements of the food and drugs act, June 30,

1906. It may be said, however, that 20 per cent of the large number of samples analyzed were found to contain commercial glucose varying in amount from small quantities (when it was apparently added to prevent granulation) to as much as 80 per cent; 12 per cent of the samples exceeded 8 per cent sucrose, and 8 per cent of the samples gave the reactions for artificial invert sugar with both ammoniacal-silver solution and anilin acetate.

Bottled honeys are frequently labeled by some floral designation, and these honeys, even when within the standard, often show a suspicious variation from the analyses of such honeys of known floral origin, especially as regards sucrose content. The microscopic examination of these honeys frequently shows an almost complete absence of pollen from the flower in question. Bee keepers and bottlers of honey are sometimes exceedingly careless in the labeling of their products and apply the name of almost any flower, thinking that they keep within the requirements of the law so long as their product is pure honey. This is a mistake, as the product should be labeled exactly according to its origin. The composition of different honey types and the possibility of establishing special standards for these are questions which will require further study.

A MICROSCOPICAL STUDY OF HONEY POLLEN.

INTRODUCTION.

METHODS OF EXAMINATION.

Little or no work appears to have been done hitherto upon the microscopy of American honeys, and the few records of the work which has been done upon European honeys were not available for consultation during the present study. It was therefore necessary to work out methods as well as results. As the structures found in honey are usually too thinly scattered for convenient inspection, it was found advantageous to dissolve the sample in several times its volume of water and centrifuge, and then examine the sediment with the microscope.

Preliminary to the examination of honey sediments, and also in connection with this investigation, it was found necessary to examine pollen taken directly from flowers for the purpose of comparison with that in the sediments. Either fresh flowers or herbarium specimens may be used. In the latter case, especially if the specimen be old, the pollen grains are apt to be so dried out and shrunken that it is difficult to determine what their normal appearance really is. If the flower be moistened with ether, the pollen grains will return to their normal size and form. Some difficulty was experienced in finding a satisfactory mounting medium. Water has a limited application, but does not clear the pollen sufficiently. Solutions of chloral hydrate or of alcohol cause the grains to burst or become distorted. Strong solutions of glycerin have the same effect, but a 10 per cent solution produces no change in form, except that it sometimes causes the protuberances to swell and, in freshly gathered pollen, it may induce the pollen tube to germinate. Glycerin gives good results as a clearing agent, and if the cover glass is sealed with a suitable cement a fairly satisfactory permanent mount is obtained. The pollen grains found in honey were usually beautifully clear and transparent, and this suggested the use of a strong solution of glucose as a medium for mounting temporary slides. The solution has to be made up frequently, as it soon becomes filled with yeast cells, and for the same reason it is not suited for making per-

manent slides. A considerable amount of oily matter is found sticking to the pollen grains of some plants which interferes with the clearing. This may be removed by placing the pollen, or the flowers containing it if they are small, on several thicknesses of filter paper and adding ether slowly. The ether dissolves the oil and passing on is absorbed by the filter paper.

STRUCTURES PRESENT IN HONEYS.

In addition to the structures normally found in honey, accidental contaminations are nearly always present. Whenever honey is exposed to the air for any length of time it is sure to collect more or less dust, which varies in character according to the conditions under which the honey was exposed. For example, the sediments frequently contained starch granules, and these were, moreover, of the kinds of starch which were being used or examined in the laboratory at the time that the honey was examined. The same fact may also account for the frequent occurrence of coniferous pollen, as a considerable quantity of pine pollen was collected and brought to the laboratory at this time. It is apparent, therefore, that care must be taken to expose the samples as little as possible, especially when examining honeys for the detection of adulteration. In honeys which have been adulterated with glucose, starch grains, frequently changed by heat, often occur, and these may have been added in the adulterant.

Crystals of various kinds are sometimes found in honey sediments. These include needle-shaped crystals and regular octahedrons and prisms identical in appearance with the calcium oxalate and calcium phosphate crystals found in urine. Crystals of dextrose, which are frequently found in large numbers in honey, were usually dissolved in preparing for centrifuging, so that they did not appear with the sediment.

Structures of animal origin are occasionally found. These include hairs and other appendages of insects, scales of Lepidoptera, and sometimes muscle fibers and fragments of tracheæ.

Structures of vegetable origin are always present. They consist of hairs and other tissue fragments, fungus spores, and pollen grains, of which the last are the only ones to occur constantly and in sufficient numbers to be of importance.

Small fragments of the comb are frequently found in extracted honeys, but are usually easy to recognize. If, however, the honey has been heated sufficiently to melt the wax, the latter collects in spherical masses which may be confused with pollen grains, from which they may be distinguished by their lack of uniformity.

NUMBER OF POLLEN GRAINS IN HONEY.

The first work undertaken in the present study had for its object to find out whether it were possible, by determining the number of pollen grains in a definite quantity of honey, to judge of the adulteration of the sample. It is obvious that if the numbers present in a large number of samples of pure honey were found to be fairly constant, any large diminution of the number would indicate adulteration. The method used was as follows: One gram of honey was weighed out into a graduated centrifuge tube, taking care to get as nearly an average sample as possible. Distilled water was added, and the tube shaken until the honey was completely dissolved. After centrifuging for about five minutes the supernatant liquid was drawn off with a siphon, leaving less than 1 cc, and water was added carefully to bring the volume exactly to 1 cc. After thoroughly mixing this water with the sediment, a drop of the liquid was placed in a Thoma blood-counting chamber for examination. As the ruled area proved to be too small the volume of the entire chamber was found accurately, and all pollen grains in the chamber were counted. In the formula $N=\frac{n}{v}$, N equals the number of pollen grains in the .1 cc of liquid in the centrifuge tube, or the number of pollen grains in 1 gram of the honey, n equals the number counted in the Thoma chamber, and v the volume of the chamber taken as a fraction of 1 cc. In actual practice ten counts were made on each sample, and the average taken as n. Duplicate counts were made in most cases by centrifuging a second sample and proceeding as with the first. The following table shows the results obtained:

Number of pollen grains in one gram of honey.

Number of sample.	Duplicate counts of pollen grains in 1 gram of honey.		Number of sample.	Duplicate counts of pollen grains in 1 gram of honey.	
	First count.	Second count.		First count.	Second count.
1	987	969	50	141	123
2	1,392	1,780	51	564	.....
3	211	193	63	2,433	2,626
4	3,154	2,361	64	582	828
5	4,106	3,912	65	2,044	2,167
6	2,150	2,361	66	2,308	2,802
7	1,516	2,079	67	1,480	987
8	211	282	68	387	528
43	3,894	3,507	92	5,410	5,058
44	158	123			

From an inspection of these data it will be seen that the estimated number of pollen grains in 1 gram of the honeys examined varies between 123 and 5,410, and that a honey like No. 5 or No. 92 could be mixed with several times its volume of glucose without making the pollen count suspiciously low.

EXAMINATION OF POLLEN FROM FLOWERS COMMONLY VISITED BY BEES.

With the cooperation of Dr. J. N. Rose, of the National Museum; Dr. C. F. Wheeler, of the Bureau of Plant Industry, and others, the pollen of a large number of flowers known or suspected to be visited by bees in different sections of the country was obtained from authentic sources and used for comparison with that found in the honeys. As the pollen of different plants more or less closely related is often found to be very similar or even identical in appearance, it is frequently impossible to carry the identification as far as the species, and for this reason it has been thought best in most cases to refer the pollen to various types, subdivided if need be, which might, for the sake of convenience, be named after the family or genus represented. The descriptive data are therefore arranged alphabetically by types with the exception of the leguminous type, which on account of its importance is considered first:

Leguminous type.—On account of the importance of leguminous plants in the production of honey, the pollen was quite thoroughly studied. The typical shape is ellipsoidal when seen from the side. Each grain has three openings arranged at equal intervals around the equator, and usually indicated by rather large protuberances. The grains are light colored, with very finely granular contents, and thin, usually smooth walls. Longitudinal grooves are often seen as faint lines running in either direction from the openings.

The pollen of white clover (*Trifolium repens* L.) may be taken as typical. The size varies from 24 μ[a] to 28 μ in length and 20 μ to 24 μ in diameter. Alsike clover (*T. hybridum* L.) pollen (Pl. II, fig. 1) differs from that of white clover only in the position of the openings, which are usually nearer one end of the grain. Red clover (*T. pratense* L.) pollen (Pl. II, fig. 2) is of the typical shape, but has an average size of 38 $\mu \times 43$ μ. The walls are rather thick and have a slightly reticulate appearance. Alfalfa (*Medicago sativa* L.) pollen (Pl. II, fig. 3) differs from the last only in the smooth and thinner wall. Sweet clover (*Melilotus* sp.) has pollen which can scarcely be distinguished from that of white clover. It is, however, a trifle longer in proportion to the diameter, averaging about 30 $\mu \times 24$ μ.

The pollen of honey locust (*Gleditsia triacanthos* L.) is like that of red clover, but somewhat more rounded. Locust (*Robinia pseudacacia* L.) pollen is roundish or even flattened so as usually to be seen on end. It has a diameter of 30 μ to 35 μ. Mesquit pollen (Pl. II,

[a] The unit employed in microscopical measurements is the micro-millimeter or micron, equal to $\frac{1}{1000}$ of a millimeter or about $\frac{1}{25000}$ of an inch. It is usually indicated by the Greek letter Mu (μ) placed after the number.

fig. 4) or algarroba [a] (*Prosopis juliflora* (Swz.) DC.) is of similar shape and has an average diameter of 32 μ. Yellow wood (*Cladrastis lutea* (Michx.) Koch or *C. tinctoria* Raf.) has very small pollen grains (12 μ × 14 μ to 16 μ) of the usual leguminous form. The pollen from the species of Acacia studied differs remarkably from that of other leguminous plants examined. The grains are compound, each consisting of 16 granules. In cat claw (*Acacia wrightii* Benth.) these grains have a diameter of 35 μ to 40 μ and a thickness of 24 μ, while each granule has a diameter of 10 μ (Pl. II, fig. 5).

Basswood or linden type.—The pollen of basswood (*Tilia americana* L.) is quite distinctive. The shape is somewhat lenticular, so as nearly always to present the same aspect. The appearance is that of a regular three-lobed figure inscribed in a circle. The three openings are subtended by the clear spaces between the lobes. The diameter averages 32 μ (Pl. II, fig. 6).

Balsam type.—*Impatiens* sp. has oblong, light-colored, thin-walled pollen grains measuring 20 μ × 24 μ to 28 μ. The four openings are located at the corners. There are a good many needle-shaped crystals in the anther tissues (Pl. III, fig. 1).

Cactus type.—*Opuntia* sp. has pollen grains 125 μ in diameter of approximately spherical shape (Pl. III, fig. 2). They have a number of faces, each provided with an opening, and the intervening space is reticulated. *Ariocarpus* sp. has spherical or subtriangular pollen, 65 μ in diameter, with a reticulated surface and only three openings.

Citrus type.—Orange and lemon pollen (Pl. III, fig. 3) are practically alike. The grains have a finely indented surface which gives them a rough appearance. There are normally four or five openings. In the samples examined the grains varied considerably in size, many appearing not to be well developed. The average size of the better developed grains was found to be 30 μ to 40 μ.

Composite type.—There is but little difference in the pollen of the various species of compositæ. It is usually rather small, spherical, provided with three openings, and covered with spines. Aster pollen (Pl. III, fig. 4) is thickly covered with short, sharp spines. The grains are 16 μ to 20 μ in diameter. Golden-rod (*Solidago* sp.) pollen is very similar and averages about 20 μ in diameter. The pollen of *Pluchea sericea* (Nutt.) Coville (*P. borealis* Gray) is 24 μ to 28 μ in diameter, with fewer, longer, and stouter spines. Bidens pollen is 24 μ in diameter and has spines a little more slender than those of the Pluchea. Sunflower (*Helianthus* sp.) pollen is 35 μ to 40 μ in diameter and rather thinly covered with sharp spines. In ragweed

[a] Hawaiian algarroba=*Prosopis juliflora;* Texas mesquit=*P. glandulosa* Torr.; Arizona mesquit=*Prosopis velutina* Wooton.; European algarroba=*Ceratonia siliqua* L. The mesquit pollen in the Texas and Arizona honeys was not identified as to species.

(*Ambrosia* sp.) the spines are reduced to rounded knobs. The grains are 20 μ in diameter (Pl. III, fig. 5).

In the chicoriaceous subtype the pollen grains are polyhedral rather than spherical, with an opening on each face. The spines are small. Dandelion (*Taraxacum taraxacum* (L.) Karst. or *T. officinale* Weber) pollen has a diameter of 35 μ to 40 μ. Pollen grains of hawkweed (*Hieracium* sp.), lion's foot (*Prenanthes* sp.), and chicory (*Cichorium intybus* L.) agree in size and shape with those of dandelion. (See Pl. III, fig. 6, for chicory pollen.) Lettuce (*Lactuca* sp.) pollen is about 28 μ in diameter.

Coniferous type.—Pine pollen (Pl. IV, fig. 1) consists of two dark bodies or floats connected by a curved sac constituting the pollen grain proper, which is clear and light colored.

Cruciferous type.—In mustard (*Brassica* sp.) the pollen grains are dark colored and spherical, with a finely indented surface and three openings situated in smooth areas. The diameter is about 32 μ. The radish pollen shown in Pl. IV, fig. 2, illustrates this type.

Cucurbitaceous type.—Melon and cucumber pollen (Pl. IV, fig. 3) is subtriangular, about 45 μ to 50 μ in diameter. The grains have coarsely granular contents and openings at the corners. Squash pollen is nearly spherical, about 120 μ in diameter, and covered with spines. It may be distinguished from cotton pollen by the shorter and less numerous spines. There are about eight openings scattered over the surface.

Evening primrose type.—*Œnothera* sp. has large, triangular pollen with roundish protuberances at the angles. The grains are 128 μ in diameter, with protuberances 40 μ or more in diameter (Pl. IV, fig. 4).

Ericaceous type.—The pollen of members of the heath family is compound, consisting of four grains united symmetrically. Where each grain is united with the others there are protuberances which have the appearance of buttresses. In *Azalea* sp. the compound grain has a diameter of 60 μ to 65 μ, with individual granules of 45 μ diameter. In mountain laurel (*Kalmia latifolia* L.) pollen (Pl IV, fig. 5) these dimensions are on the average 44 μ and 32 μ, respectively. In *Clethra alnifolia* L. the pollen is much like that of white clover.[a] The grains are 24 μ long and have three openings placed in very evident longitudinal grooves. *Catalpa* sp. (order Bignoniaceæ) has compound pollen similar to that of laurel, 80 μ in diameter. The grains have a very dark color, and the surface is covered with polygonal rough areas separated by smooth lines.

Grape type.—Grape pollen is thin-walled, roundish, or subtriangular, with three, or rarely four, openings. The average diameter is 28 μ.

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[a] The Clethraceæ is considered by some botanists as an independent family, by others as a subfamily, of the Ericaceæ.

Grass type.—The grasses have ovoidal pollen which is frequently almost spherical. The contents are often denser in the larger end. The surface is very smooth, and there is a single opening at the larger end, sometimes centrally placed, but usually located more or less to one side. Orchard grass has pollen 32 μ long, timothy pollen is 36 μ long (Pl. IV, fig. 6), and in corn the average length is about 100 μ.

Guava type.—Psidium guajava L. has small triangular pollen grains 16 μ in diameter, with clear spaces at the angles (Pl. V, fig. 1).

Honeysuckle type.—The common honeysuckle (*Lonicera* sp.) has roundish or subtriangular pollen 65 μ to 70 μ in diameter, having three openings and a covering of very small spines (Pl. V, fig. 2).

Labiate type.—The pollen grains of the mints have the shape of flattened ellipsoids; that is, they have three axes of different length. When viewed in the direction of the shortest axis the shape is that of an ellipse, an elongated hexagon, or an ellipse with six indentations corresponding in position to the six openings, which are sometimes indicated by very small protuberances. These openings are arranged at equal intervals, two of them marking the ends of the medium diameter. When viewed from the side the grain appears marked by grooves passing between the poles of the shortest diameter. The pollen of the different species is so much alike as to be in most cases indistinguishable. Pollen grains of *Salvia ballotæflora* Benth., *Nepeta cataria* L., and *Mentha arvensis* L. have a length of 34 μ to 36 μ, while those of Audibertia are sometimes 60 μ long. The cultivated scarlet sage has pollen grains of the usual labiate type 68 μ in length (Pl. V, fig. 3).

Liliaceous type.—Lily pollen is rather coarse; the grains are ellipsoidal and usually have evident longitudinal furrows. Pollen grains of *L. longiflorum* Thunb. are 90 μ to 120 μ in length and have a reticulated surface. *L. tigrinum* Ker. is used to illustrate this type (Pl. V, fig. 4).

Magnolia type.—Trees of this family have flattened pollen grains which when placed in liquids present a peculiar appearance. A clear glassy swelling is seen along one side, extending well over the ends, which gives the grains a purse-like appearance. In tulip tree (*Liriodendron tulipifera* L.) pollen the grains are 60 μ long (Pl. V, fig. 5). Other magnolias have larger or smaller grains.

Mallow type.—Plants of the mallow family have very large spherical pollen grains covered with sharp spines which are proportionately rather short. Cotton (*Gossypium hirsutum* or *G. herbaceum* L.) has pollen grains frequently 125 μ in diameter with spines 5 μ long (Pl. V, fig. 6). *Malvastrum americanum* (L.) Torr. or *M. tricuspidatum* Gray has similar pollen grains which average 70 μ in diameter.

Morning-glory type.—The pollen of morning-glory (*Ipomœa* sp.) is spherical and prickly, resembling that of cotton. Its diameter is 120 μ.

Polygonum type.—*Polygonum persicaria* L. has spherical pollen 40 μ in diameter with the surface coarsely but evenly reticulate, due to intersecting ridges (Pl. VI, fig. 1). Buckwheat (*Fagopyrum fagopyrum* (L.) Karst. or *F. esculentum* Moench.) has dark-colored, ellipsoidal pollen 40 μ and over, usually 50 μ to 60 μ, in length, with a rough surface (Pl. VI, fig. 2). Wild buckwheat (*Eriogonum* sp.) pollen is much like that of buckwheat, but usually smaller and lighter in color.

Rosaceous type.—The plants of the rose family do not have very distinctive pollen. In general it may be said that the pollen grains have a subtriangular form with openings at the corners which sometimes appear to be covered with a shallow cap. Protuberances from these openings are usually cleft. Apple pollen has a diameter of 36 μ to 44 μ; *Rubus* sp. (Pl. VI, fig. 3), 30 μ to 35 μ; hawthorn (*Cratægus* sp.), 45 μ to 50 μ; *Prunus* sp. about like that of *Rubus*. Strawberry pollen is ellipsoidal, 30 μ to 32 μ in length and covered with fine longitudinal striations.

Tupelo type.—*Tupelo* (*Nyssa* sp.) has subtriangular pollen of a clear yellowish color (Pl. VI, fig. 4). In *N. sylvatica* Marsh the diameter is 32 μ to 36 μ and in *N. aquatica* L. 40 μ to 45 μ.

Umbelliferous type.—Wild carrot (*Daucus carota* L.) has pollen similar to that of clover, but more narrow in proportion; size, 16 μ by 24 μ to 28 μ (Pl. VI, fig. 5).

Besides these types the following may be mentioned to complete the list, which includes nearly all the pollens identified in the American honeys examined.

Oak pollen looks much like that of the apple; size 36 μ. *Cleome integrifolia* Torr.-Gray or *C. serrulata* Pursh. has roundish pollen 14 μ in diameter, with three openings. The hop (*Humulus lupulus* L.) has spherical pollen, with three openings subtended by clear areas. This form is not characteristic of the hop, however, as it is found in St. John's-wort and probably in a number of other plants. *Hicoria aquatica* (Michx. f.) Brit. has roundish pollen 40 μ in diameter, with three openings located in thickened areas of the wall. Willow and poplar have ellipsoidal pollen 24 μ to 30 μ in length, with three curved longitudinal lines. *Rhus glabra* L. has similar pollen 40 μ in length. Persimmon (*Diospyros virginiana* L.) pollen (Pl. VI, fig. 6) is nearly spherical or slightly ellipsoidal, with the same kind of longitudinal grooves and a length of 50 μ to 56 μ. Palm and palmetto pollen is also ellipsoidal. The pollen of mangrove (*Rhizophora mangle* L.) is much like that of clover. The grains are 24 μ long.

Gooseberry (*Ribes* sp.) pollen is roundish and has several openings. The diameter is about 34 μ in the case of *R. viscosissimum* Pursh. Chestnut (*Castanea dentata* (Marsh) Borkh.) has ellipsoidal pollen grains 16 μ in length (Pl. VI, fig. 7), which can scarcely be distinguished from those of yellowwood. *Lobelia spicata* Lam. pollen is of the ellipsoidal type. The grains are rather pointed and are 30 μ to 35 μ in length.

IDENTIFICATION OF POLLENS IN THE HONEYS EXAMINED.

In the following account, the honeys examined are taken up in order and the different kinds of pollen found are enumerated, referring in most cases to types rather than species. Some of these types, such as the subtriangular type found in the rose family, the ellipsoidal type with three curved longitudinal grooves, and the hop type, are found in such unrelated groups of plants, that, except in rare cases, exact identification is impossible. It will be seen at once that a honey made from nectar gathered from a single species of plant is very rarely, if ever found. The numbers attached correspond to those given in the description table beginning on page 22, by which means the sample may be further identified.

AMERICAN HONEYS.

1. *Alfalfa* (Nev.). Clover pollen most abundant. Others found were Alfalfa, Grass, Ericaceous, Coniferous, and Rosaceous types and a Composite, probably Pluchea. A few grains of pollen of a conical form and very characteristic appearance were found, size 34 $\mu \times 62$ μ. They were found only in honeys from Nevada and the type was not determined.

2. *Alfalfa* (Nebr.). Alfalfa, White clover, and another Leguminous pollen predominated. Other types found were Malvaceous or possibly Morning-glory, Composite, Coniferous, and Ellipsoidal.

3. *Alfalfa* (Kans.). Alfalfa and Cruciferous types.

4. *Alfalfa* (Nev.). Conical pollen grains like those found in No. 1 were quite common. Alfalfa, Clover, Cruciferous, Grass, Rosaceous, and Coniferous types were also found. There were two kinds of Composite pollen and a few grains of 16 μ to 20 μ diameter of the Ellipsoidal type.

5. *Alfalfa* (Ariz.). Alfalfa, Clover, Composite (three kinds), Polygonum, Cruciferous, Rosaceous, Honeysuckle, and Grass types. A few subtriangular pollen grains 25 μ in diameter were found, also some pointed ellipsoidal grains 35 μ long, possibly Lobelia type.

6. *Alfalfa* (Utah). Alfalfa, Clover, and Corn pollen found, also Composite, Cruciferous, Grass, and Polygonum types.

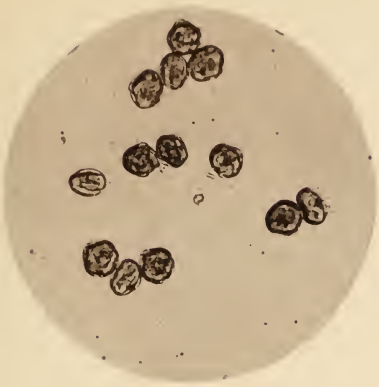


FIG. 1.—ALSIKE CLOVER.

FIG. 2.—RED CLOVER.

FIG. 3.—ALFALFA.

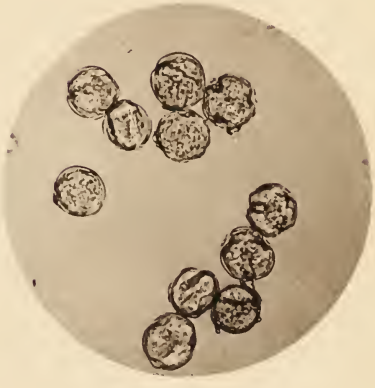


FIG. 4.—MESQUIT.

FIG. 5.—CAT CLAW.

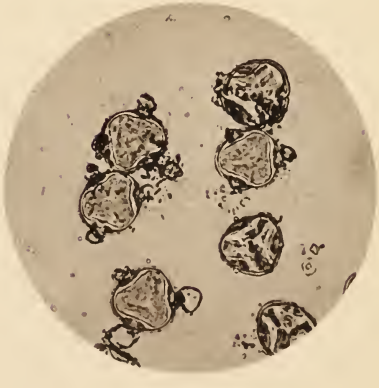


FIG. 6.—BASSWOOD.

POLLEN GRAINS. (X 250.)

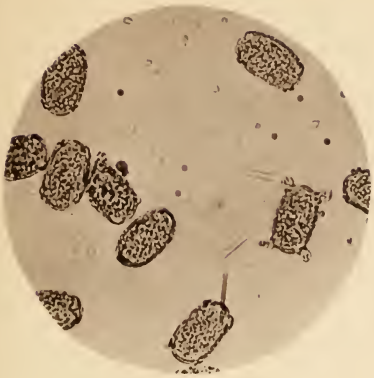


FIG. 1.— BALSAM.

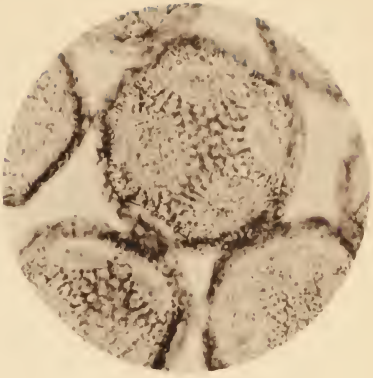


FIG. 2.— OPUNTIA.

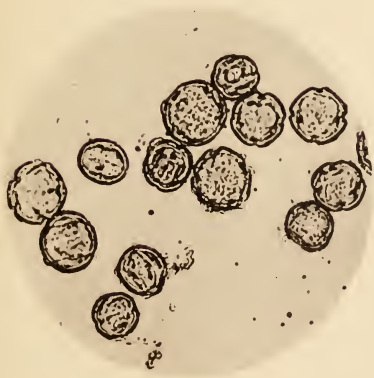


FIG. 3.— LEMON.

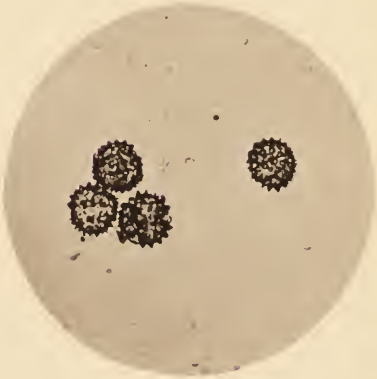


FIG. 4.— ASTER.

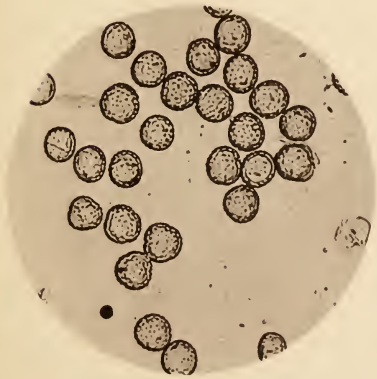


FIG. 5.— RAGWEED.

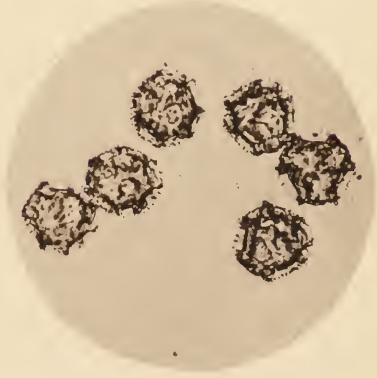


FIG. 6.— CHICORY.

POLLEN GRAINS. (X 250.)

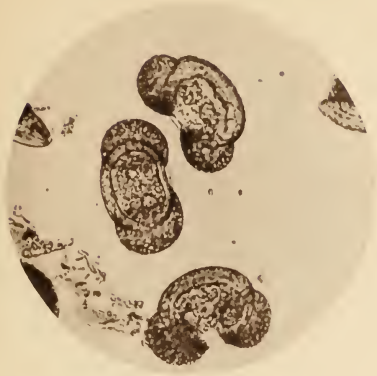


FIG. 1.— PINE.

FIG. 2.— RADISH.

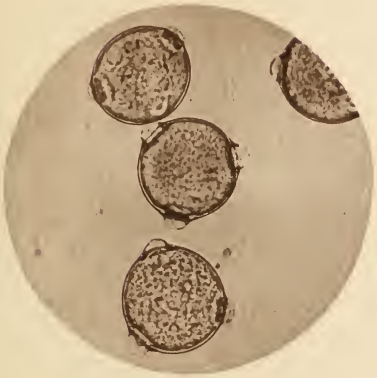


FIG. 3.— CUCUMBER.

FIG. 4.— EVENING PRIMROSE.

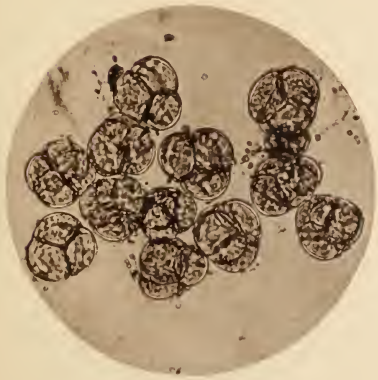


FIG. 5.— MOUNTAIN LAUREL.

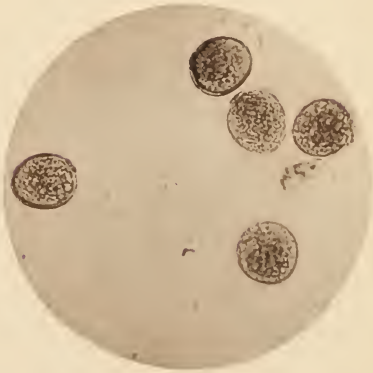


FIG. 6.— TIMOTHY.

POLLEN GRAINS. (X 250.)

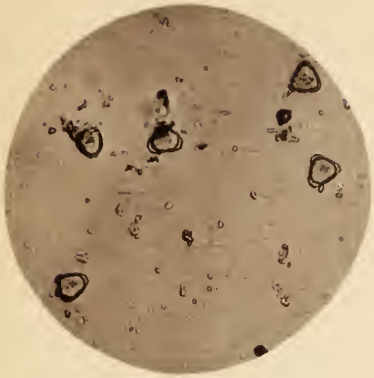


FIG. 1.— GUAVA.

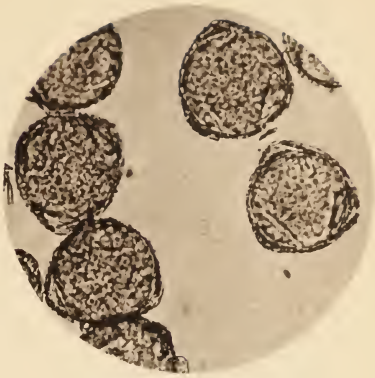


FIG. 2.— HONEYSUCKLE.

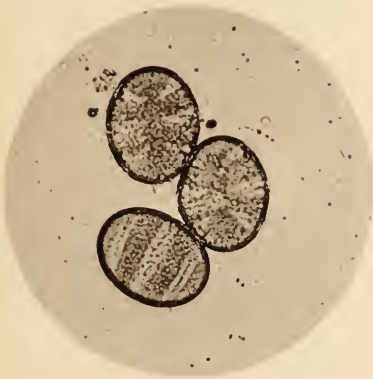


FIG. 3.— SCARLET SAGE.

FIG. 4.— TIGER LILY.

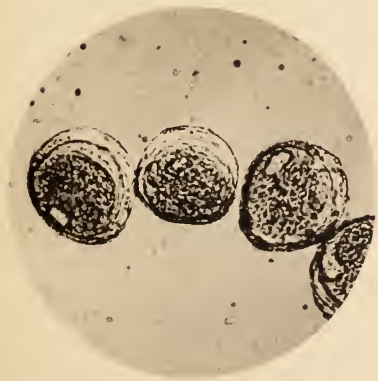
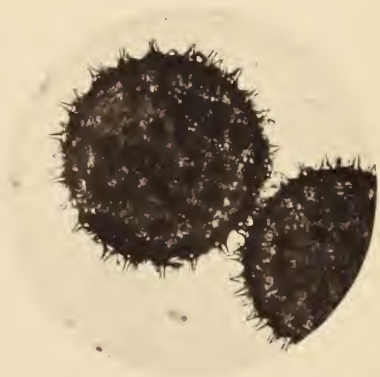


FIG. 5.— TULIP TREE.



F.G. 6.— COTTON.

POLLEN GRAINS. (X 250.)

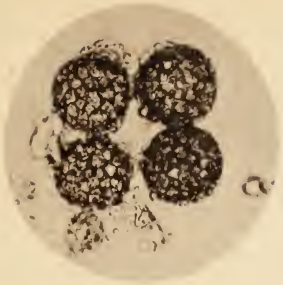


FIG. 1.— SMARTWEED.

FIG. 2.— BUCKWHEAT.

FIG. 3.— RASPBERRY.

FIG. 4.— TUPELO.

FIG. 5.— CARROT.

FIG. 6.— PERSIMMON.

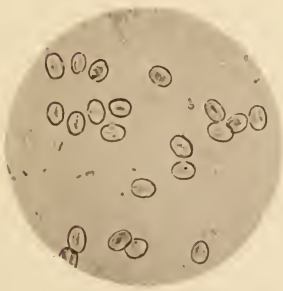


FIG. 7.— CHESTNUT.

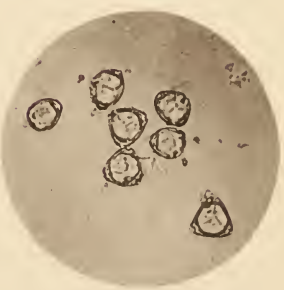


FIG. 8.— EUCALYPTUS.

POLLEN GRAINS. (X 250.)

7. *Alfalfa* (Colo.). Alsike clover and possibly a little Alfalfa pollen. Evening primrose, Honeysuckle, Grass, Coniferous, and Cruciferous types.

8. *Alfalfa* (Kans.). Clover, Alfalfa, Polygonum, Composite (two kinds), Grass, Honeysuckle, Evening primrose, and Ellipsoidal types.

9. *Clover* (Mich.). Clover, Basswood, Alfalfa, Red clover, Coniferous, Composite, Ellipsoidal, and Rosaceous types.

10. *Clover* (Minn.). Most of the pollen was from White clover. Others were Cruciferous, Alfalfa, Ellipsoidal, Rosaceous (*Rubus* sp.), Grass, Labiate, Corn, Composite (two kinds, one probably Golden-rod), Coniferous, and Polygonum types.

11. *Clover* (Minn.). Clover pollen most abundant. Others were Alfalfa, Composite (probably Golden-rod), Buckwheat, Rosaceous, and Cruciferous types.

12. *Clover* (Me.). Clover, Composite (probably Golden-rod), Red clover, Coniferous, and Rosaceous types.

13. *Clover* (Wis.). Clover, Cruciferous, Coniferous, Hop, Leguminous, Grass, Alfalfa, Rosaceous, Basswood, and Composite types.

14. *White Clover* (Ill.). White clover, Ellipsoidal (probably Willow or Poplar), Grass, Hop, Composite (two kinds, one of them probably Golden-rod), Basswood, Alfalfa, and Polygonum types.

15. *White Clover* (Ohio). Clover, Locust, Alfalfa, Buckwheat, Composite (probably Golden-rod), Rosaceous (*Rubus* sp.), Polygonum, and Subtriangular types.

16. *White Clover* (N. Y.). Clover and Rosaceous pollen most abundant. Corn, Buckwheat, Red clover, Grass, Basswood, and Cruciferous types also found.

17. *White Clover* (Iowa). Clover, Basswood, Umbelliferous, Ellipsoidal, Grass, Alfalfa, Coniferous, Composite, and Cruciferous types.

18. *White Clover* (Mich.). Mostly clover pollen. Others were Basswood, Grass, and Coniferous types.

19. *White Clover* (Mo). White and Alsike clover pollen most abundant. Others were Alfalfa, Composite (two kinds), Leguminous, Grass, Polygonum, Coniferous, and Cruciferous types.

20. *White Clover* (Del.). Clover pollen most abundant. Others were Chestnut, Locust, Rosaceous, Grass, and Composite types.

21. *White Clover* (Mich.). Clover, Alfalfa, Basswood, Grass, Coniferous, Ellipsoidal, and Umbelliferous types.

22. *White Clover* (Oreg.). Clover, Grass, Leguminous, Coniferous, Rosaceous, and Ellipsoidal types.

23. Sample too small for examination.

24. *Alsike Clover* (Mont.). Alsike clover, Alfalfa, Rosaceous, Umbelliferous, Composite (two kinds, one of which was Dandelion), Grass, Corn, and Coniferous types.

25. *Alsike Clover* (Wis.). Alsike clover, Alfalfa, Basswood, Grass, and Composite types.

26. *Alsike Clover* (Wash.). Alsike clover pollen was the only kind found with the exception of a very few grains of Grass pollen. This honey probably comes as near as any to being made from one kind of blossom.

27. *Sweet Clover* (Ohio). Melilotus and other clovers, Corn, Hickory, Basswood, Locust, and Coniferous types.

28. *Sweet Clover* (Nev.). Melilotus, Alfalfa, Mesquit, Grass, Coniferous, Composite, Rosaceous, and Ericaceous types.

29. *Melilotus* (Ala.). Most of the pollen present was from Tupelo. Others were Clover, Corn, Evening primrose, Melilotus, Magnolia, Grass, Hop, Cotton, Persimmon, Buckwheat, Composite, Ellipsoidal, and Subtriangular types.

30. *Melilotus* (Nebr.). Pollen of the Ellipsoidal type predominated, with very little Melilotus pollen. Others were Clover, Alfalfa, Grass, Polygonum, Composite, and Ericaceous types.

31. *Cat Claw* (Tex.). Cat-claw (Acacia) pollen predominated. Rosaceous, Hop, Mesquit, Labiate, Coniferous, Evening primrose, Cruciferous, Cactus, Magnolia, Cotton, Composite (three kinds), Ellipsoidal (four kinds), and subtriangular types also found.

32. *Cat Claw* (Tex.). Very little Cat-claw (Acacia) pollen found. Mesquit pollen predominated, with a few grains of the Coniferous and Ellipsoidal types.

33. *Mosquiet* (*Mesquit*) (Ariz.). Mesquit, Composite (two kinds), Acacia, Cruciferous, Grass, Coniferous, and Rosaceous types. Spherical pollen, with four openings like those found in No. 53 but larger, 36 μ in diameter.

34. *Meskeet* (*Mesquit*) (Tex.). Ellipsoidal (two kinds), Coniferous, Grass, Mesquit, Acacia, Composite, Yellowwood, Cactus, Cruciferous, and Labiate types.

35. See Hawaiian Honeys, page 85.

36. *Locust* (Ohio). Clover, Locust, Hop, Tulip-tree, Composite, Ellipsoidal, and Rosaceous types.

37. *Yellowwood* (Ark.). Ellipsoidal (two kinds), Composite (two kinds), Alfalfa, Clover, Corn, Basswood, Grass, Cotton, and Yellowwood (Cladrastis) types.

38. *Dandelion* (Nev.). Dandelion pollen predominated. Conical pollen grains like those found in No. 1 were quite common. Others were Grass, Clover, Rosaceous, Coniferous, Grape, Alfalfa, Polygonum, Composite (two kinds), Coniferous, and Cruciferous types.

39. *Dandelion* (Me.). Clover pollen predominated, with very little Dandelion pollen. Others were Ellipsoidal (probably Willow), Rosaceous (*Rubus* sp.), Red clover, Coniferous, and Composite types.

40. *Golden-rod* (Wis.). Basswood, Clover, Chestnut, Composite (possibly Golden-rod), and Rosaceous (*Rubus*) types.

41. *Golden-rod* (Me.). Five kinds of pollen of the Composite type were found, which probably include Dandelion, Golden-rod, and Aster. Others were White and Red clover, Cruciferous, Ellipsoidal (probably Willow), Basswood, Rosaceous (*Rubus* sp.), and Ericaceous types.

42. *Golden-rod* (N. J.). Chestnut pollen very abundant. Others were Balsam, Clover, Composite (including Dandelion and Golden-rod), Rosaceous, Basswood, Red clover, Persimmon, Tulip-tree, Corn, Grape, Grass, Polygonum, Umbelliferous, and Malvaceous or Morning-glory types.

43. *Indian Arrow Weed* (Ariz.). Mesquit and a Composite pollen, probably Pluchea, predominated. Other types were Cruciferous, Polygonum, Acacia, Honeysuckle, and probably Yellowwood.

44. *Wild Aster* (N. J.). Composite pollen, probably from Wild Aster, and Balsam pollen predominated. Others found were Basswood, Clover, Chestnut, and Ellipsoidal types.

45. *Spanish Needle* (Mo.). Composite (three kinds, including Dandelion and Bidens, the latter very abundant), Clover, Alfalfa, Grass, Polygonum, Coniferous, and Malvaceous, or possibly Morning-glory, types.

46. *Apple* (Mass.). Apple pollen most common. Other types present were White clover, Dandelion, Locust, Grass, Hop, and Cruciferous.

47. *Apple* (Mass.). Apple pollen predominated. Locust, Cruciferous, Composite, Grass, Ericaceous, and Ellipsoidal types.

48. *Raspberry* (Me.). Raspberry pollen predominated. Others were Alsike and Red clover, Composite (probably Aster or Golden-rod), and Polygonum types.

49. *Wild Red Raspberry* (Wis.). Clover and Raspberry pollen abundant. Others were Alfalfa, Basswood, Grass, Dandelion, Rosaceous, Umbelliferous, and Composite types.

50. *Buckwheat* (Wis.). Buckwheat, Polygonum, Alfalfa, Clover, Corn, Composite, Basswood, and Labiate types.

51. *Buckwheat* (Mich.). Buckwheat, Clover, Alfalfa, Corn, and two kinds of Composite pollen.

52. *Wild Buckwheat* (Cal.). Eriogonum, Clover, Coniferous, Grass, Grape, and Composite types.

53. *Wild Buckwheat* (Cal.). Eriogonum, Grape, Coniferous, and Composite types. Small grains of Ellipsoidal type 22 μ in length. Roundish grains 22 μ in diameter and provided with four openings.

54. *Heartsease* (N. J.). The same kinds of pollen found as in No. 42, except that those of the Malvaceous or Morning-glory type were lacking.

55. *Wild Pennyroyal* (Fla.). Labiate, Ellipsoidal (two kinds), Composite (two kinds), Subtriangular, Guava, Leguminous, Honeysuckle, Tupelo, and Magnolia types.

56. *Sage* (Cal.). Labiate (probably Sage), Grape, Ellipsoidal, Cruciferous, and Eriogonum types. Roundish pollen, with four openings like that found in No. 53, was quite common.

57. *Cotton* (Ala.). Clover, Melilotus, Magnolia, Corn, Locust, Basswood, Buckwheat, Cotton, Composite, Subtriangular, and Ellipsoidal types.

58. *Cotton* (S. C.). Cotton, Composite (two kinds), Corn, and Clover types.

59. *Cotton* (Ark.). Composite pollen of four kinds, one of which is probably Pluchea, was most abundant. Other types found were Cotton, Clover, Coniferous, Corn, Cruciferous, and Grass.

60. *Hop Vine* (Miss.). Tupelo, Yellowwood, Ellipsoidal (two kinds), Corn, and Grass types.

61. *Melon* (Ill.). Clover, Melon, Cruciferous, Polygonum, Alfalfa, Basswood, Composite (two kinds), and Ellipsoidal types.

62. See under Hawaiian Honeys, page 85.

63. *Basswood* (Ark.). Most numerous were ellipsoidal pollen grains 40 μ long. Clover, Corn, Basswood, Composite, and Leguminous types. Octahedral crystals numerous.

64. *Basswood* (W. Va.). Leguminous (probably Red clover), Basswood, Clover, Composite, and Coniferous types.

65. *Basswood* (Miss.). Clover pollen most abundant. Alfalfa, Composite (two kinds), Corn, Basswood, and Rosaceous types.

66. *Basswood* (Minn.). Clover and Basswood pollen predominated. Alfalfa, Grass, Cruciferous, and Composite types.

67. *Basswood* (Mich.). Most of the pollen found was Basswood. Other types were Alsike clover, Rosaceous, Alfalfa, Composite (two kinds), Buckwheat, and Cruciferous.

68. *Basswood* (Wis.). Basswood, Alsike clover, Grass, Coniferous, Composite, Malvaceous (or possibly Morning-glory), and Leguminous types.

69. *Cabbage-palm* (Fla.). Most of the pollen was of the Magnolia type, 30 μ to 35 μ in length. Others found were Coniferous, Composite, Polygonum, Leguminous, and Ellipsoidal types. The last may have come from the cabbage-palm.

70. *Saw-palmetto* (Fla.). Most of the pollen was of the Magnolia type, with a few Ellipsoidal grains, which may have been saw-palmetto pollen.

71. *Palmetto Berry Dew* (Fla.). Magnolia, Composite, Ellipsoidal, Leguminous, and Rosaceous types.

72. *Poplar* (S. C.). Pollen of Tulip-tree (White poplar) most abundant. Others were Tupelo, Rosaceous (*Rubus*), Ellipsoidal,

Composite, Cucurbitaceous, Cruciferous, Coniferous, Persimmon, and Leguminous types.

73. *Willow* (Wis.). Ellipsoidal (three kinds, one of them probably Willow), Buckwheat, Locust, Rosaceous, and Cruciferous types.

74. *Laurel* (Fla.). Labiate, Magnolia, Composite (two kinds), Ellipsoidal (three kinds), Subtriangular, Hop, Cucurbitaceous, and Ericaceous types.

75. *White Alder* (R. I.). White alder pollen (*Clethra alnifolia*) was quite abundant. Others were Composite (two kinds, probably Aster and Golden-rod), Chestnut, Ellipsoidal, Polygonum, Balsam, Buckwheat, Clover, Rosaceous, Labiate, Magnolia, and Umbelliferous types.

76. *Orange* (Cal.). Grape, Composite (two kinds), Orange, Evening primrose, Leguminous, Ericaceous, Eriogonum, Balsam, Ellipsoidal, and Rosaceous types.

77. *Sumac* (Ark.). The most common pollen was of the Ellipsoidal type, possibly Sumac pollen. Others were Composite (two kinds), Ericaceous, Clover, Polygonum, Corn, Basswood, Alfalfa, Persimmon, Cotton, Mesquit, Cruciferous, Leguminous, and Labiate types.

78. *Sumac* (Ark.). Composite (two kinds), Persimmon, Hop, Mesquit, Corn, Ellipsoidal (possibly Sumac), Basswood, Hickory, Buckwheat, and Coniferous types.

79. *Sumac* (Ind. T.). Ellipsoidal pollen, possibly Sumac, very abundant. Others were Clover, Corn, Hop, Composite, and Umbelliferous types.

80. *Mangrove* (Fla.). Pollen grains all of the Magnolia type except a very few of the Tupelo and Ellipsoidal types.

81. *Mangrove* (Fla.). The Magnolia type of pollen very abundant. Others were Labiate, Tupelo, Hop, Grass, Ellipsoidal (two kinds), Ericaceous, and Composite types.

82. *Tupelo* (Fla.). Tupelo, Persimmon, and Ellipsoidal types.

83. *Tupelo* (Fla.). Tupelo, Persimmon, Hop, Ellipsoidal (three kinds), and roundish pollen with four openings similar to that found in No. 53.

84. *Whitewood* (N. J.). A few grains of pollen from Whitewood (Tulip-tree) were found. Others were Chestnut, Rosaceous (two kinds, one of them from *Rubus* sp.), White and Red clover, Balsam, Cruciferous, Composite (two kinds, one of them Dandelion), Corn, Buckwheat, Melon, Grass, Basswood, Ellipsoidal, and Labiate types.

85. *Hickory* (Ark.). Corn pollen very abundant. Others were Composite (three kinds), Grass, Clover, Chestnut or Yellowwood, Hickory, Polygonum, Coniferous, Ericaceous, and Ellipsoidal types. Numerous octahedral crystals 8 μ and less in diameter were found.

86. *White Oak* (Ark.). Corn pollen very abundant. Others were Ellipsoidal, Composite (two kinds), Grass, Labiate, Leguminous, and Coniferous types.

87. See Hawaiian Honey, page 85.

88. See Hawaiian Honey, page 85.

89. *Fall Flowers* (Minn.). Four kinds of pollen of the Composite type were found, of which one, probably Goldenrod, was the most abundant type of pollen in the honey. Others were Clover, Polygonum, Cruciferous, Alfalfa, Labiate, Corn, Balsam, Grass, Basswood, Malvaceous (or possibly Morning-glory), and Subtriangular types.

90. *Fall Flowers* (Iowa). Ellipsoidal (about four kinds), Clover, Melilotus, Alfalfa, Basswood, Honeysuckle, Corn, Evening primrose, Composite, and Cruciferous types.

91. *Fruit Bloom* (Me.) Clover pollen most abundant. Other types were Rosaceous (*Rubus* and *Pyrus* sp.), Red clover, Composite, and Cruciferous.

92. *Basswood and Fall Bloom* (Minn.). Clover, Alfalfa, Composite (two kinds), Umbelliferous, Buckwheat, Basswood, Corn, and Cruciferous types.

93. *Catnip and Cleome* (Nebr.). Clover, Alfalfa, Composite, Labiate (probably Catnip), Grass, Polygonum, Corn, and Ellipsoidal types.

HAWAIIAN HONEYS.

The sediments from Hawaiian honeys differ from those of American honeys only in the kinds of pollen present. As pollen from only a few Hawaiian flowers was available, the attempt at identification was not carried so far as in the case of the American honeys, and only a few samples were examined. The following types of pollen may be mentioned in addition to those given above, and any characteristic types which were not identified are described in connection with the samples in which they were found.

Thevetia nereifolia Juss. has large triangular pollen grains 90 μ to 100 μ in diameter and of a characteristic appearance.

Waltheria americana L. has spherical pollen 40 μ to 45 μ in diameter with five openings.

Metrosideros villosa Smith (labeled *M. lutea* Gray) has triangular pollen like that of guava, but larger, 20 μ in diameter.

Eucalyptus type. Pollen of *Eucalyptus* sp. is triangular, with clear corners connected by shallow curved grooves. The grains have a diameter of 20 μ (Pl. VI, fig. 8).

Lantana camara L. has spherical pollen 30 μ to 35 μ in diameter, with three openings and rather thick walls.

Mezoneuron brachycarpum Benth. has nearly spherical pollen 35 μ in diameter. The surface is rough, owing to slight indentations, with

the exception of three narrow areas extending nearly to the poles, which are smooth and slightly depressed and contain the openings.

35. *Algarroba.* Algarroba pollen most abundant. Others were Malvastrum, Cruciferous, and Ellipsoidal types.

62. *Prickly Pear.* Large quantities of Algarroba pollen were found. Others were Malvastrum, Cactus, Grass (possibly sugar-cane pollen), and Composite types, the last of the Chicoriaceous subtype as in No. 97.

87. *Blue Gum* (*Eucalyptus globulus* Labill.). Eucalyptus pollen was about the least abundant of any type found in this sample. Others were Algarroba, Composite (two kinds), and Mezoneuron types. Bright yellow, spherical pollen grains of a coarsely granular appearance and having eight openings and a diameter of 20 μ to 22 μ were common. There were also a few light-colored spherical grains, 24 μ in diameter, with three openings and a coarsely indented surface.

88. *Ohia Lehua* (*Metrosideros villosa* Smith). Metrosideros, Eucalyptus, Composite (two kinds), Algarroba, Cucurbitaceous types, spherical yellow pollen as in No. 87, and a few others lacking distinctive characters.

94. "*Seaweed with blue flowers.*" This sample contained very little pollen. There were a few stray grains of the Waltheria and Algarroba types and some too much collapsed to be recognized.

95. *Verbena bonariensis, Ipomœa, Thevetia nereifolia, Malvastrum americanum, Lantana, Guava, and Keawe.* Magnolia (two kinds), Leguminous, Composite, Guava, Algarroba, Lantana, Mezoneuron types, and spherical granular pollen 60 μ in diameter. Neither Ipomœa, Thevetia, nor Malvastrum pollen, which are all quite characteristic, was found.

96. *Honeydew from sugar cane.* The pollen found was of the Algarroba and Acacia types. The grains were few.

97. *Honeydew from sugar cane; flowers of Lantana, Waltheria americana, Heteropogon contortus, Verbena bonariensis, and Guava.* Pollen of Acacia and Malvastrum types predominated. Others were Guava, *Waltheria americana* (very few), Lantana, Mezoneuron, and Composite types. There were two kinds of pollen of the Composite type, one of them like that of the Chicoriaceous subtype, but smaller than that of the Dandelion, 24 μ in diameter.

98. *Thimbleberry and forest flowers.* Eucalyptus, Leguminous, and a few grains of the Algarroba type. Reticulated pollen 55 μ in diameter as in the Polygonum type, Composite pollen of the Chicoriaceous subtype as in No. 97. Round, dark colored, pollen 40 μ to 44 μ in diameter with indented walls and three or four openings. Pollen 28 μ in diameter and resembling the Basswood type but subtriangular in outline instead of round.

99. *Honeydew from sugar cane; flowers of Algarroba.* Algarroba pollen very abundant. Others were composite (two kinds, one of

them of the Chicoriaceous subtype as in No. 97). Waltheria, Mezoneuron, Subtriangular, Cactus, Eucalyptus, Leguminous, and Malvastrum types.

100. *Honeydew from sugar cane; flowers of Algarroba and weeds.* Algarroba pollen very abundant. Others were Malvastrum, Acacia (70 μ to 75 μ in diameter), Balsam, Composite, and Magnolia types and a few grains lacking distinctive character.

KEY TO POLLENS COMMONLY FOUND IN AMERICAN HONEYS.

The following key has been prepared to facilitate the identification of pollens found in honeys. It is necessarily incomplete and will probably lead to only approximately accurate results for reasons already explained. The pollens are described as they appear in honey or after standing some time in a glucose solution, and not necessarily as they appear when mounted in water or other ordinary mounting media:

I. Pollen grains, compound.
  A. Granules 4, symmetrically arranged.
    a. Grains under 50 μ in diameter——Mountain laurel.
    b. Grains 60 μ to 65 μ in diameter——Azalea.
    c. Grains 80 μ in diameter, dark colored surface covered with polygonal rough areas——Catalpa.
  B. Granules 16, in 3 parallel planes——Acacia.
II. Pollen grains, simple.
  A. Pollen spiny.
    a. Pollen grains over 50 μ in diameter, spherical——Malvaceous type.
      1. Pollen grains 100 μ or more in diameter.
        A. Spines conical, closely arranged—Cotton, Morning-glory.
        B. Spines pointed and nearly cylindrical; less numerous; several openings——Squash.
    b. Pollen over 50 μ in diameter; subtriangular, spines very small. Honeysuckle.
    c. Pollen under 50 μ in diameter.
      1. Grains spherical; openings three——Composite type.
      2. Grains polyhedral, with an opening on each face. Chicoriaceous type.
  B. Pollen not spiny.
    a. Pollen grains with single opening or with no definite opening.
      1. Purse-shaped pollen——Magnolia type.
      2. Ovoidal pollen with opening at larger end——Grass type.
      3. Pollen grain provided with two membranous floats or wings. Coniferous type.
    b. Pollen grains normally with three openings: spherical, ellipsoidal or triangular.
      1. Surface of the grains coarsely reticulated.
        A. Pollen grains ellipsoidal; over 75 μ in length. Liliaceous type.
        B. Pollen grains ellipsoidal: under 75 μ in length.
          a. Pollen dark colored; about 50 μ in length. Buckwheat.

β. Pollen lighter colored and usually smaller than in α.....Eriogonum.
C. Pollen grains spherical.....Polygonum.
D. Pollen grains spherical or subtriangular; over 50 μ in length.....Cactus type.
2. Surface of the ellipsoidal grains covered with fine longitudinal striations.....Strawberry.
3. Surface of the grains not striated or coarsely reticulated.
A. Grains ellipsoidal or spherical.
α. Openings located in longitudinal three-curved grooves.
a. Grains over 50 μ in length; nearly spherical. Persimmon.
b. Grains about 40 μ in length. Sumac and others.
c. Grains under 35 μ in length. Willow, poplar, lobelia, and others.
β. Longitudinal grooves when present not three-curved.
a. Pollen grains less than 20 μ in length. Chestnut, yellowwood, cleome.
b. Pollen grains between 20 μ and 35 μ in length.
1. Grains very narrow in proportion to the length; the length being to the diameter as 3 or 4 to 2..Umbelliferous type.
2. Grains less narrow in proportion to the length; length about 30 μ....Melilotus.
3. Grains still less narrow in proportion to the length.
*Protuberances large; length of grain 24 μ to 28 μ.
+Protuberances in equator of grain. White clover.
++Protuberances not equatorial, i. e., nearer one end of the grain. Alsike clover.
**Protuberances smaller.
+Grains ellipsoidal, 24 μ long, smooth. White alder (*Clethra alnifolia*), mangrove, and others.
++Grains ellipsoidal or spherical, 28 μ long, smooth. Grape and others.
+++Grains ellipsoidal or spherical; dark colored; surface rough, with protuberances in smooth areas; length 30 μ to 35 μ. Cruciferous type.
c. Pollen grains more than 35 μ in length.
1. Surface of grains smooth; contents finely granular.....Alfalfa.
2. Surface of grains slightly rough; contents coarsely granular....Red clover.

B. Grains triangular, subtriangular, or lenticular.

a. Openings subtended by clear areas.

a. Lenticular pollen 30 μ to 35 μ in diameter, presenting the appearance of a three-lobed figure inscribed in a circle_____Basswood.

b. Pollen nearly spherical, about 25 μ in diameter _____Hop type.

c. Pollen triangular; angles clear; diameter 20 μ or less.

1. Angles connected by shallow curved grooves; diameter 20 μ.

Eucalyptus type.

2. Angles not connected by grooves; diameter 16 μ_____Guava type.

β. Openings not subtended by clear areas.

a. Protuberances from openings usually cleft.

Rosaceous type.

1. Pollen grains 30 μ to 35 μ in diameter.

Rubus, Prunus.

2. Pollen grains 35 μ to 45 μ in diameter.

Pyrus.

3. Pollen grains 45 μ to 50 μ in diameter.

Cratægus.

b. Protuberances not cleft.

1. Openings in thickened areas of the wall; grains lenticular_____Hickory type.

2. Openings not in thickened areas of the wall.

*Pollen grains over 100 μ in diameter with very large protuberances.

Evening primrose.

**Pollen grains over 50 μ in diameter; contents coarsely granular.

Melon, cucumber.

***Pollen grains less than 50 μ in diameter; contents clear or very finely granular.

+Pollen grains lenticular or nearly spherical; diameter 30 μ to 35 μ.

Mesquit, locust.

++Pollen grains subtriangular; diameter 32 μ to 45 μ__Tupelo type.

c. Pollen grains normally with more than three openings.

1. Pollen grains oblong and sac-shaped, with four openings situated at the corners_____Balsam type.

2. Pollen grains nearly spherical, normally with four or five openings arranged equatorially; diameter 30 μ to 40 μ.

Citrus type.

3. Pollen grains approximately spherical, but having a number of faces each provided with an opening; the intervening space reticulated; diameter over 100 μ.

Cactus type (Opuntia).

4. Pollen grains having the shape of flattened ellipsoids; openings six, about equally distributed around the greatest circumference_____Labiate type.

CHEMICAL LITERATURE ON HONEY FROM 1892 TO 1907.

Compiled by A. H. Bryan.

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